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NASA/ROCKWELL INTERNATIONAL SPACE SHUTTLE ORBITER ABORT HEATING--ETC(U)
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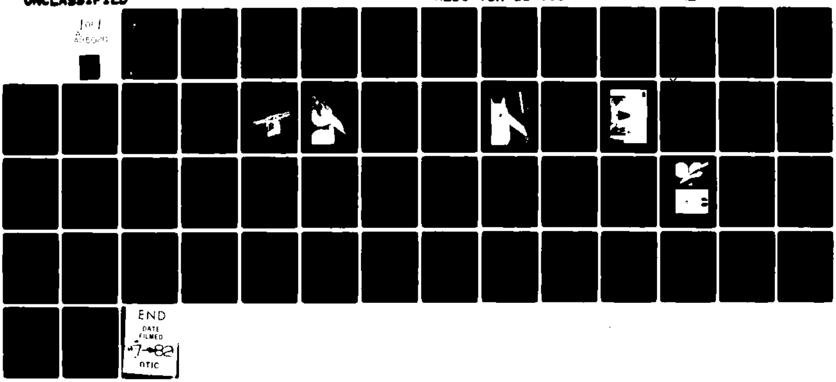

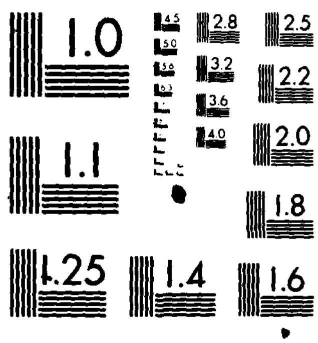


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# NASA/ROCKWELL INTERNATIONAL SPACE SHUTTLE ORBITER ABORT HEATING TEST (OH-111)

L. A. Ticatch and K. W. Nutt
Calspan Field Services, Inc.

November 1981

Final Report for Period September 25-30, 1981

Approved for public release; distribution unlimited.



**ARNOLD ENGINEERING DEVELOPMENT CENTER**
**ARNOLD AIR FORCE STATION, TENNESSEE**
**AIR FORCE SYSTEMS COMMAND**
**UNITED STATES AIR FORCE**

## NOTICES



## APPROVAL STATEMENT

This report has been reviewed and approved.

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Deputy for Operations

Approved for publication:

FOR THE COMMANDER

John M. Rampy

JOHN M. RAMPY, Director
Aerospace Flight Dynamics Test
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| REPORT DOCUMENTATION PAGE | | READ INSTRUCTIONS BEFORE COMPLETING FORM |
|---|---|---|
| 1. REPORT NUMBER<br>AEDC-TSR-81-V36 | 2. GOVT ACCESSION NO.<br>AD-A115020 | 3. RECIPIENT'S CATALOG NUMBER |
| 4. TITLE (and Subtitle)<br>NASA/ROCKWELL INTERNATIONAL SPACE SHUTTLE ORBITER ABORT HEATING TEST (OH-111) | | 5. TYPE OF REPORT & PERIOD COVERED<br>Final Report<br>September 25-30, 1981 |
| | | 6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s)<br>L. A. Ticatch and K. W. Nutt, Calspan Field Services, Inc./AEDC Division | | 8. CONTRACT OR GRANT NUMBER(s) |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>Arnold Engineering Development Center<br>Air Force Systems Command<br>Arnold Air Force Station, TN 37389 | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS<br>Program Element 921E01<br>Control No. 9E01 |
| 11. CONTROLLING OFFICE NAME AND ADDRESS<br>Johnson Space Center (NASA-JSC(ES3))<br>Houston, Texas 77058 | | 12. REPORT DATE<br>November 1981 |
| | | 13. NUMBER OF PAGES<br>53 |
| 14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) | | 15. SECURITY CLASS. (of this report)<br>UNCLASSIFIED |
| | | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE<br>N/A |

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Available in Defense Technical Information Center (DTIC).

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

heat transfer
thin skin
space shuttle orbiter
hypersonic testing

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Thin-skin thermocouple heat transfer tests were conducted on two 0.0175 scale and one 0.04 scale models of the Space Shuttle orbiter at attitudes that would be encountered in a transatlantic abort maneuver. The model angles of attack ranged from 40 to 55 degrees with yaw angle varying from -2 to 2 degrees. Data were obtained at Mach 8 in the AEDC-VKF Hypersonic Wind Tunnel B at free-stream Reynolds numbers ranging from $0.5 \times 10^6$ to $1.5 \times 10^6$ per foot.

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## CONTENTS



## APPENDIXES

I. ILLUSTRATIONS



II. TABLES

## NOMENCLATURE

| | |
|---|---|
| ALPI | Indicated pitch angle, deg |
| ALPHA | Angle of attack, deg |
| ALPPB | Prebend angle, deg |
| b | Model skin thickness, in. |
| B | Wing span, in. (see Fig. 4) |
| BV | Height of model vertical tail, in. (see Fig. 4) |
| c | Model material specific heat, Btu/lbm-°R |
| C | Local chord of wing or vertical tail, in. (see Fig. 4) |
| DELTAE | Elevon deflection angle, deg |
| DELTASB | Speed brake deflection angle, deg |
| DELTBF | Body flap deflection angle, deg |
| DTW/DT | Derivative of the model wall temperature with respect to time, °R/sec |
| H(REF) | Reference heat transfer coefficient (see Appendix III) |
| H(TR), H(TT) H(0.9TT), H(0.85TT) | Heat-transfer coefficient based on recovery temperature, TR (TR = TT, 0.9TT, or 0.85TT assumed for these data), QDOT/(TR-TW), Btu/ft$^2$-sec-°R |
| L | Reference length, in. (see Fig. 4) |
| M, MACH NO. | Free-stream Mach number |
| MU | Dynamic viscosity based on free-stream temperature, lbf-sec/ft$^2$ |

| | |
|---|---|
| MUTT | Dynamic viscosity based on TT, lbf-sec/ft$^2$ |
| P | Free-stream static pressure, psia |
| PT | Tunnel stilling chamber pressure, psia |
| PT2 | Stagnation pressure downstream of a normal shock, psia |
| PHI | Radial angle location of thermocouple in model coordinates, deg (see Figs. 4 and 9) |
| PHII | Indicated roll angle, deg |
| Q | Free-stream dynamic pressure, psia |
| QDOT | Heat-transfer rate, Btu/ft$^2$-sec |
| RE | Free-stream unit Reynolds number, ft$^{-1}$ |
| RHO | Free-stream density, lbm/ft$^{-3}$ |
| RN | Reference nose radius, (0.0175 ft or 0.04 ft, *determined by model scale*) |
| RUN | Data set identification number |
| STFR | Stanton number based on reference conditions (see Appendix III) |
| T | Free-stream static temperature, °R |
| TC NO | Thermocouple identification number |
| TIME | Elapsed time from lift-off, sec |
| TR | Assumed recovery temperature, °R |
| TT | Tunnel stilling chamber temperature, °R |
| TW | Model surface temperature, °R |

| | |
|---|---|
| V | Free-stream velocity, ft/sec |
| X | Model scale axial coordinate from model nose or leading edge of wing or vertical tail (see Fig. 4 and 9) in. |
| XO | Full scale axial coordinate from a point 235 in. ahead of the orbiter nose (see Fig. 9), in. |
| Y | Model scale lateral coordinate (see Fig. 4), in. |
| YAW | Yaw angle of model, deg |
| YO | Full scale lateral coordinate, in. |
| Z | Model scale vertical coordinate (see Fig. 4), in. |
| ZO | Full scale vertical coordinate, in. |
| $\rho$ | Model material density, lbm/ft$^3$ |

# 1.0 INTRODUCTION

The work reported herein was performed by the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), under Program Element 921E01, Control Number 9E01, at the request of the Johnson Space Center (NASA-JSC(ES3)), Houston, Texas. The NASA-JSC (ES3) program manager was Mrs. Dorothy B. Lee and the Rockwell International project engineers were Mr. C. L. Berthold and Mr. J. Gee. The results were obtained by Calspan Field Services, Inc./AEDC Division, operating contractor for the Aerospace Flight Dynamics testing effort at the AEDC, AFSC, Arnold Air Force Station, Tennessee. The tests were performed in the von Karman Gas Dynamics Facility (VKF), under AEDC Project No. C628VB.

The test was performed in the 50-in.-diam Hypersonic Wind Tunnel (B) at the von Karman Gas Dynamics Facility (VKF) during the period September 25, 1981 to September 30, 1981. Data were recorded at Mach number 8 for nominal Reynolds numbers ranging from $0.5 \times 10^6$ to $1.5 \times 10^6$ per foot. The nominal model angles of attack ranged from 40 to 55 degrees with model yaw angles varying from -2 to 2 degrees. All thin-skin thermocouple data were obtained from three space shuttle orbiter models designated 56-0, 60-0, and 83-0.

The test had a NASA/Rockwell designation of OH-111. The test objective was to obtain thin-skin heat transfer data on the space shuttle orbiter model at attitudes that would be encountered in a transatlantic abort maneuver.

A summary of the test data transmitted is shown in Table 1. Inquiries to obtain copies of the test data should be directed to NASA-JSC (ES3), Houston, Texas 77058. A microfilm record has been retained in the VKF at AEDC.

# 2.0 APPARATUS

## 2.1 TEST FACILITY

Tunnel B (Fig. 1), is a closed circuit hypersonic wind tunnel with a 50-in. diam test section. Two axisymmetric contoured nozzles are available to provide Mach numbers of 6 and 8 and the tunnel may be operated continuously over a range of pressure levels from 20 to 300 psia at Mach number 6, and 50 to 900 psia at Mach number 8, with air supplied by the VKF main compressor plant. Stagnation temperatures sufficient to avoid air liquefaction in the test section (up to 1350°R) are obtained through the use of a natural gas fired combustion heater. The entire tunnel (throat, nozzle, test section, and diffuser) is cooled by integral, external water jackets. The tunnel is equipped with a model injection system, which allows removal of the model from the test section while the tunnel remains in operation. A description of the tunnel may be found in Ref. 1.

## 2.2 TEST ARTICLES

Three Space Shuttle orbiter models were used to obtain the thin-skin thermocouple data for this test. Two of the test articles were 0.0175 scale models of the full orbiter and were designated as the 60-0 and 56-0 models. The third model was a 0.04 scale of the front half of the orbiter and was identified as the 83-0 model. All of the models were supplied by Rockwell International.

The 60-0 model was a 0.0175 scale thin-skin thermocouple model of the Rockwell International Vehicle 5 configuration. The model was constructed of 17-4 PH stainless steel with a nominal skin thickness of 0.030 in. at the instrumented areas. All thermocouples were spot welded to the thin-skin inner surface.

A photograph of the 60-0 model injected in the tunnel is shown in Fig. 2. A sketch of the 60-0 model installation in the tunnel is shown in Fig. 3. The basic dimensions and coordinate definitions for the 0.0175 scale models are shown in the sketch presented in Fig. 4. The deflection angles of the speedbrake, elevons, and body flaps were all set at zero throughout the test.

The 56-0 model used for this test was model number 2B of the material "LH" 56-0 phase change paint model series. This was a 0.0175 scale model with the same external contour as the 60-0 model. The pilot side of the fuselage consisted of a thin-skin thermocouple insert contoured to the vehicle lines. This insert was constructed of 17-4 stainless steel with a nominal skin thickness of 0.020 in. at the thermocouple locations. A photograph of the 56-0 model injected in the tunnel is shown in Fig. 5. A sketch of the 56-0 model installation is shown in Fig. 6. The dimensions and coordinate system presented in Fig. 4 also apply to the 0.0175 scale 56-0 model.

The 83-0 model was a 0.04 scale model of the forward half of the orbiter. This model was also constructed of 17-4 PH stainless steel with a nominal skin thickness of 0.030 in. A photograph of the 83-0 model in the installation tank beneath the test section is shown in Fig. 7. The installation sketch of the 83-0 model is shown in Fig. 8 and the coordinate system and basic dimensions for the 83-0 model are presented in Fig. 9.

## 2.3 TEST INSTRUMENTATION

### 2.3.1 Test Conditions

The instrumentation, recording devices, and calibration methods used to measure the primary tunnel and test data parameters are listed in Table 2a along with the estimated measurement uncertainties. The range and estimated uncertainties for primary parameters that were calculated from the measured parameters are listed in Table 2b.

2.3.2 Test Data

The 60-0 model was instrumented with 600 thirty-gauge iron-constantan and Chromel®-constantan thermocouples. Only 250 of these thermocouples were used on this test. Thermocouple locations for this model are presented in Fig. 10; the dimensional locations and skin thickness for the thermocouples connected on this test are listed in Table 3. The thermocouples identified by a number only are iron-constantan. The thermocouples identified by a number followed by the letter A or C are Chromel-constantan that were added to the model. The letter D after a thermocouple number designates an iron-constantan thermocouple in a new location on the OMS pod.

The 56-0 model instrumentation consisted of 80 thirty-gauge Chromel-constantan thermocouples located on the thin skin insert. All of these thermocouples were connected on this test. The thermocouple locations for this model are presented in Fig. 11. The dimensional locations and skin thicknesses are listed in Table 4.

For this test only 250 of the 482 thirty-gauge Chromel-constantan thermocouples on the 83-0 model were connected. The thermocouple locations for this model are illustrated in Fig. 12. The dimensional locations and skin thicknesses for the thermocouples used on this test are listed in Table 5.

# 3.0 TEST DESCRIPTION

## 3.1 TEST CONDITIONS

A summary of the nominal test conditions at each Mach number is given below:

| M | PT, psia | TT, °R | Q, psia | P, psia | RE x $10^{-6}$, $ft^{-1}$ |
|---|---|---|---|---|---|
| 8 | 100 | 1250 | 0.5 | 0.010 | 0.5 |
| 8 | 205 | 1250 | 1.0 | 0.02 | 1.0 |
| 8 | 325 | 1300 | 1.5 | 0.035 | 1.5 |

A test summary showing the configurations tested and the variables for each is presented in Table 6.

## 3.2 TEST PROCEDURE

### 3.2.1 General

In the VKF continuous flow wind tunnels (A, B, C), the model is mounted on a sting support mechanism in an installation tank directly underneath the tunnel test section. The tank is separated from the tunnel by a pair of fairing doors and a safety door. When closed, the fairing doors, except for a slot for the pitch sector, cover the opening to the tank and the safety door seals the tunnel from the tank area. After the model is prepared for a data run, the personnel access door to

the installation tank is closed, the tank is vented to the tunnel flow, the safety and fairing doors are opened, and the model is injected into the airstream. After the data are obtained, the model is retracted into the tank and the sequence is reversed with the tank being vented to atmosphere to allow access to the model in preparation for the next run. A given injection cycle is termed a run, and all the data obtained are identified in the data tabulations by a run number.

#### 3.2.2 Thin-Skin Thermocouple

Prior to each test run, the model temperatures were monitored to ensure that the model was nominally isothermal. The model was then injected at the desired test attitude as the data acquisition sequence commenced. The model remained on the tunnel centerline for about three seconds and was then retracted into the installation tank. The model was then cooled while being repositioned for the next injection.

A 256 channel multiplexing analog-to-digital converter was used in conjunction with a Digital Equipment Corporation (DEC) PDP-11 computer and a DEC-10 computer to record the temperature data. The system sampled the output of each thermocouple approximately 13 times per second.

#### 3.2.3 Oil-Flow

Oil-flow testing was done on the 60-0 model and the 83-0 model. For oil-flow testing the models were painted black for contrast, and in general, a white oil with a viscosity of 25 centistokes was applied to the surface with a sponge for each run. The oil was applied differently on the first two runs of the 83-0 model. On runs 77 and 78, coatings of 800-centistoke and 200-centistoke white oil were applied over a coating of clear Dow Corning oil with a viscosity of 100 centistokes. The model was positioned to the test attitude and injected into the tunnel flow for about 20 sec. During this time, four still cameras photographed the model at 2-second intervals. Locations of the cameras and camera numbers are specified in Table 7. After the model was retracted from the tunnel flow, it was cooled and cleaned before oil was reapplied for the next test run. Oil flow runs are specified in the Test Data Summary, Table 6.

### 3.3 DATA REDUCTION

#### 3.3.1 Thin-Skin Thermocouple Data

The reduction of thin skin temperature data to coefficient form normally involves only the calorimeter heat balance for the thin skin as follows:

$$\text{QDOT} = \rho bc \ \text{DTW/DT} \tag{1}$$

$$\text{H(TR)} = \frac{\text{QDOT}}{\text{TR-TW}} = \frac{\rho bc \ \text{DTW/DT}}{\text{TR-TW}} \tag{2}$$

Thermal radiation and heat conduction effects on the thin-skin element are neglected in the above relationship and the skin temperature

response is assumed to be due to convective heating only. It can be shown that for constant TR, the following relationship is true:

$$\frac{d}{dt} \ln \left[\frac{TR-TI}{TR-TW}\right] = \frac{DTW/DT}{TR-TW} \qquad (3)$$

Substituting Eq. (3) in Eq. (2) and rearranging terms yields:

$$\frac{H(TR)}{\rho bc} = \frac{d}{dt} \ln \left[\frac{TR-TI}{TR-TW}\right] \qquad (4)$$

By assuming that the value of $H(TR)/\rho bc$ is a constant, one can see that the derivative (or slope) must also be constant. Hence, the term

$$\ln \left[\frac{TR-TI}{TR-TW}\right]$$

is linear with time. This linearity assumes the validity of Eq. (2) which applies for convective heating only. The evaluation of conduction effects will be discussed later.

The assumption that H(TR) and c are constant are reasonable for this test although small variations do occur in these parameters. The variations of H(TR) caused by changing wall temperature and by transition movement with wall temperature are trivial for the small wall temperature changes that occur during data reduction. The value of the model material specific heat, c, was computed by the relation

$$c = 0.0797 + (5.556 \times 10^{-5})TW \quad \text{(17-4 PH stainless steel)} \qquad (5)$$

The maximum variation of c over any curve fit was less than 1.5 percent. Thus, the assumption of constant c used to derive Equation 4 was reasonable. The value of density used for the 17-4 PH stainless steel skin was $\rho = 490\ lbm/ft^3$, and the skin thickness, b, for each thermocouple is listed in Tables 3, 4 or 5.

The right side of Equation 4 was evaluated using a linear least squares curve fit of 15 consecutive data points to determine the slope. The curve fit was started at approximately the time the model arrived on the tunnel centerline. For each thermocouple the tabulated value of H(TR) was calculated from the slope and the appropriate values of $\rho bc$; i.e.,

$$H(TR) = \rho bc \frac{d}{dt} \ln \left[\frac{TR-TI}{TR-TW}\right] \qquad (6)$$

To investigate conduction effects a second value of H(TR) was calculated at a time one second later. A comparison of these two values was used to identify those thermocouples that were influenced by significant conduction (or system noise). The data for a given thermocouple were deleted* if these values of H(TR) differed by more than 35 percent. In general, conduction and/or noise effects were found to be negligible.

Since the value of TR is not known at each thermocouple location it has become standard procedure to use three assumed values of TR. The assumed values are 1.0TT, 0.9TT and 0.85TT. The use of these assumed values of TR provides an indication of the sensitivity of the heat-transfer coefficients to the value of TR assumed. As can be noted in the tabulated data, there are large percentage differences in the values of the heat-transfer coefficients calculated from the three assumed values. Therefore, if the data are to be used for flight predictions, the value selected for TR is obviously very important and is a function of model location and boundary layer state.

The heat-transfer coefficient calculated from Eq. 4 was normalized using the Fay-Riddell stagnation point coefficient, H(REF), based on a nose radius of 1.0 ft full scale (see Appendix III). The reference nose radius, RN, used to calculate H(REF) is either 0.0175 ft or 0.04 ft as determined by the model scale.

## 3.4 UNCERTAINTY OF MEASUREMENTS

In general, instrumentation calibrations and data uncertainty estimates were made using methods recognized by the National Bureau of Standards (NBS). Measurement uncertainty is a combination of bias and precision errors defined as:

$$U = \pm (B = t_{95}S)$$

where B is the bias limit, S is the sample standard deviation and $t_{95}$ is the 95th percentile point for the two-tailed Student's "t" distribution (95-percent confidence interval), which for sample sizes greater than 30 is taken equal to 2.

Estimates of the measured data uncertainties for this test are given in Table 2a. The data uncertainties for the measurements are determined from in-place calibrations through the data recording system and data reduction program.

Propagation of the bias and precision errors of measured data through the calculated data was made in accordance with Ref. 2 and the results are given in Table 2b.

*The word DELETE is used on the tabulated data to identify these thermocouples.

## 4.0 DATA PACKAGE PRESENTATION

Heat-transfer coefficients were obtained at selected locations on the 56-0, 60-0, and 83-0 models of the space shuttle orbiter. Sample tabulated data are presented in Appendix IV.

Representative data from the upper centerline (PHI = 180 deg) of the 83-0 model are presented in Fig. 13. Data from two runs are presented as a sample of data repeatability.

Representative oil-flow data of the 60-0 model are shown in Fig. 14.

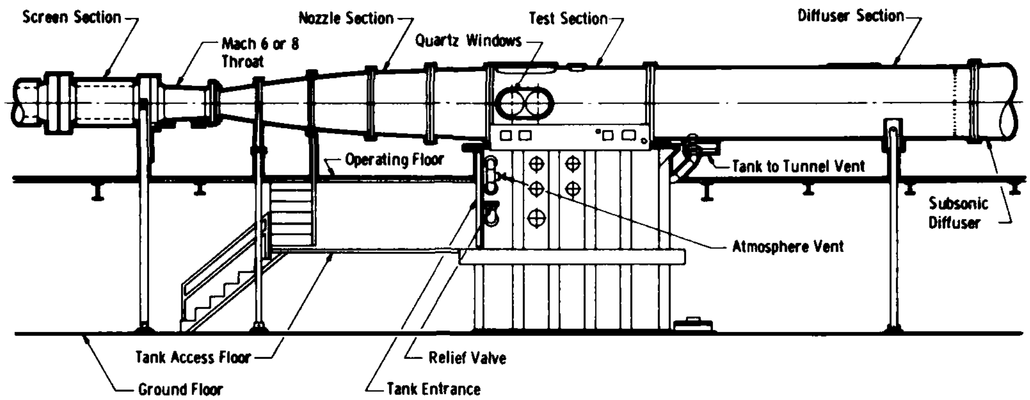
## REFERENCES


1. Test Facilities Handbook (Eleventh Edition). "von Karman Gas Dynamics Facility, Vol. 3." Arnold Engineering Development Center, June 1979.

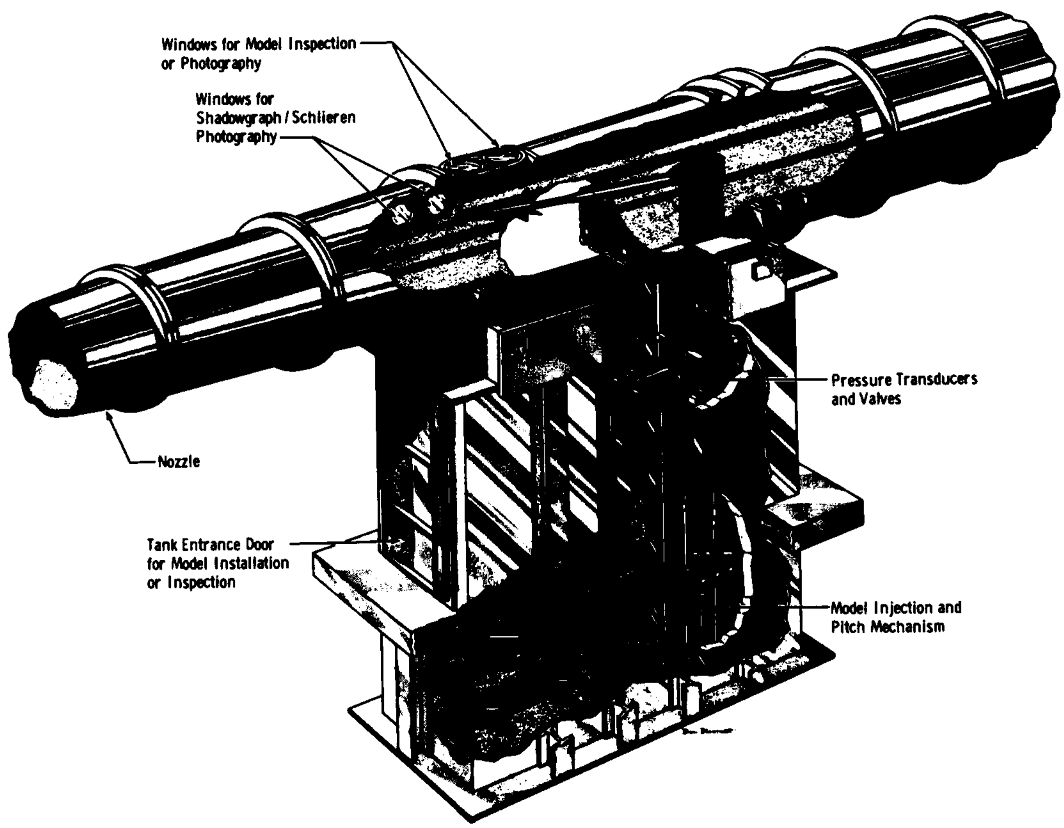
2. Thompson, J. W. and Abernethy, R. B. et al. "Handbook Uncertainty in Gas Turbine Measurements." AEDC-TR-73-5 (AD755356), February 1973.

APPENDIX I

ILLUSTRATIONS




a. Tunnel assembly




b. Tunnel test section

Fig. 1. Tunnel B

A E D C
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Figure 2. Installation Photograph of 60-0 Model

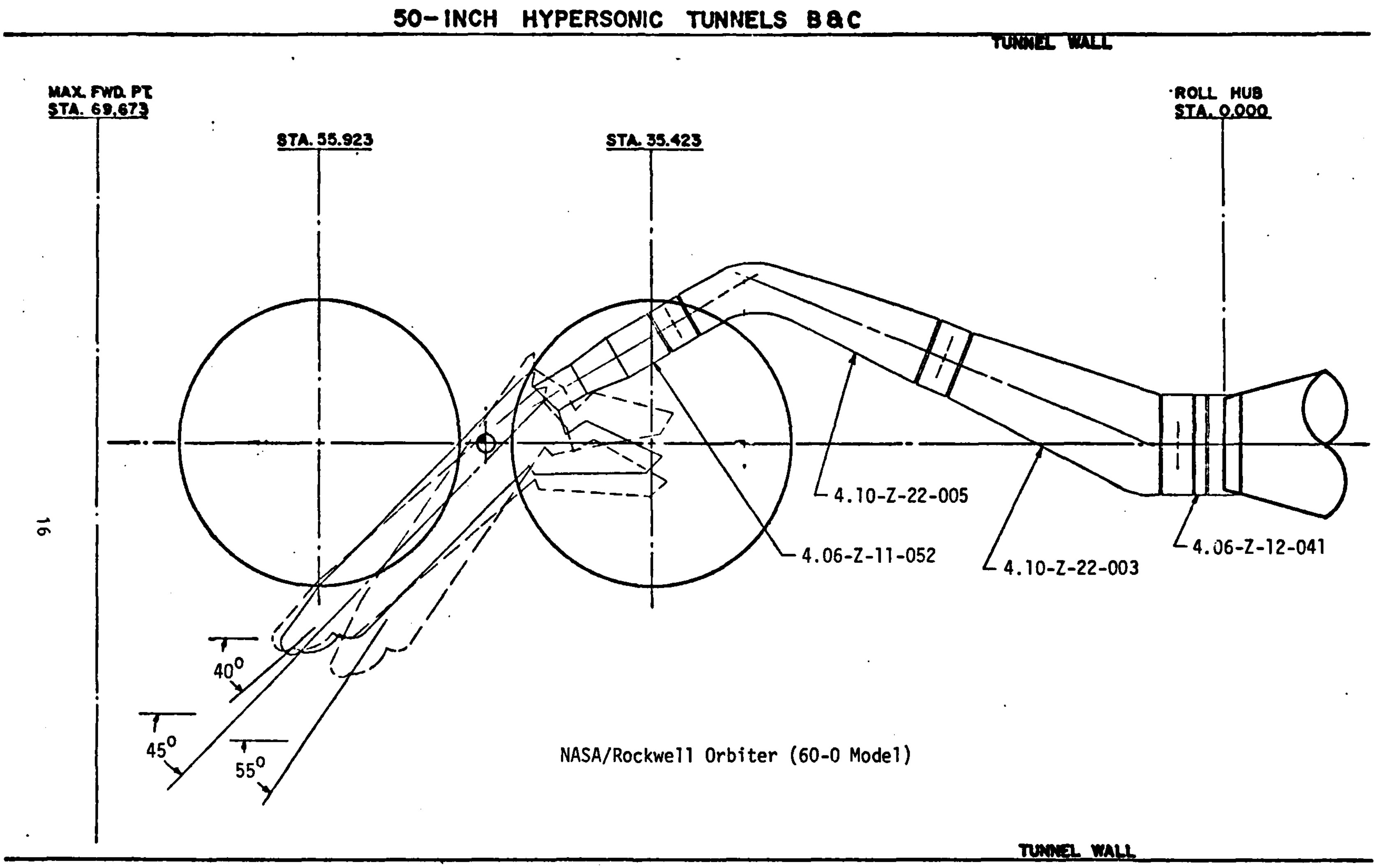



Figure 3. 60-0 Model Installation

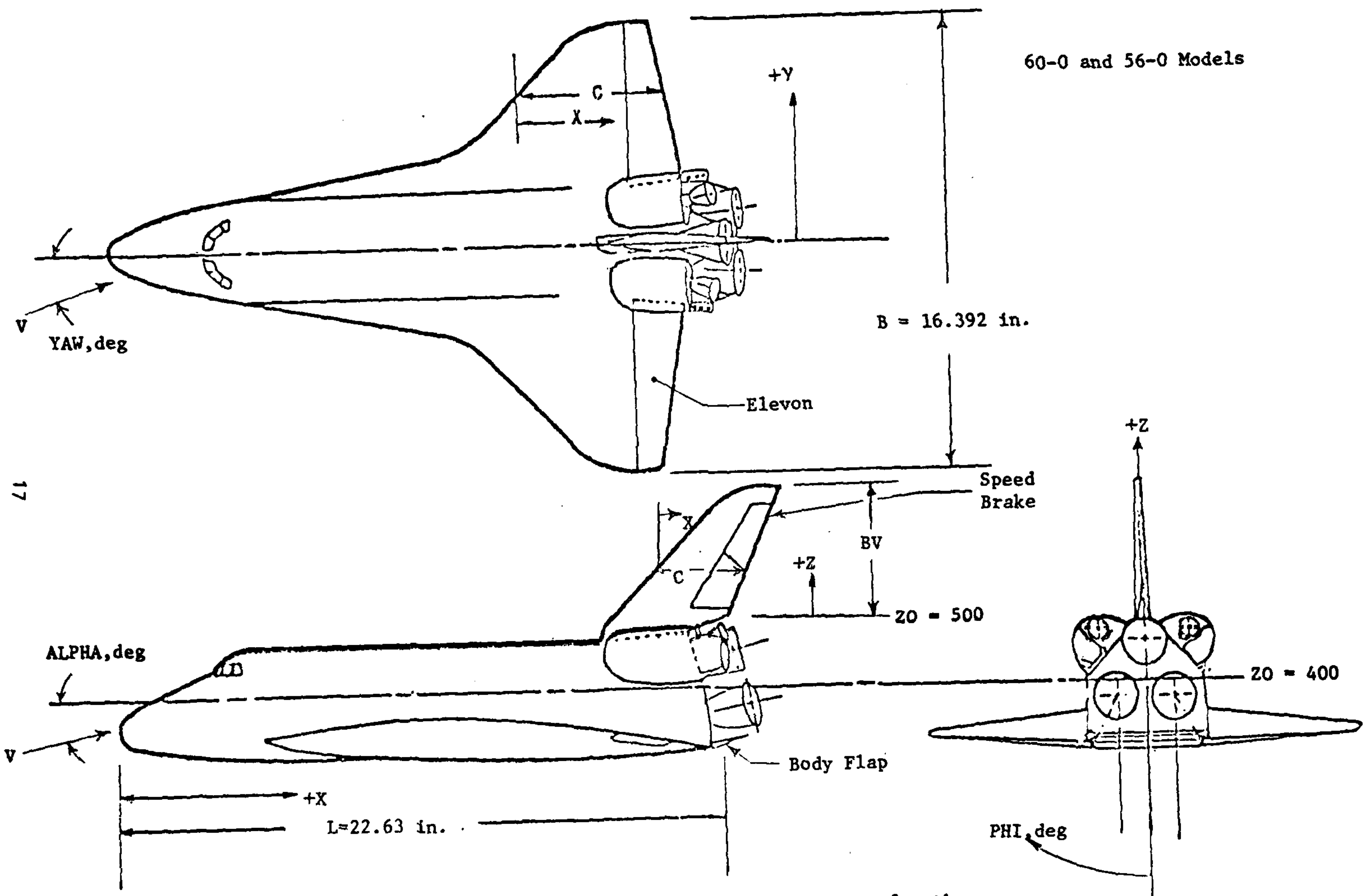



Fig. 4. Basic Dimensions and Coordinate System for the 0.0175 Scale Orbiter Models


Figure 5. Installation Photograph of 56-0 Model

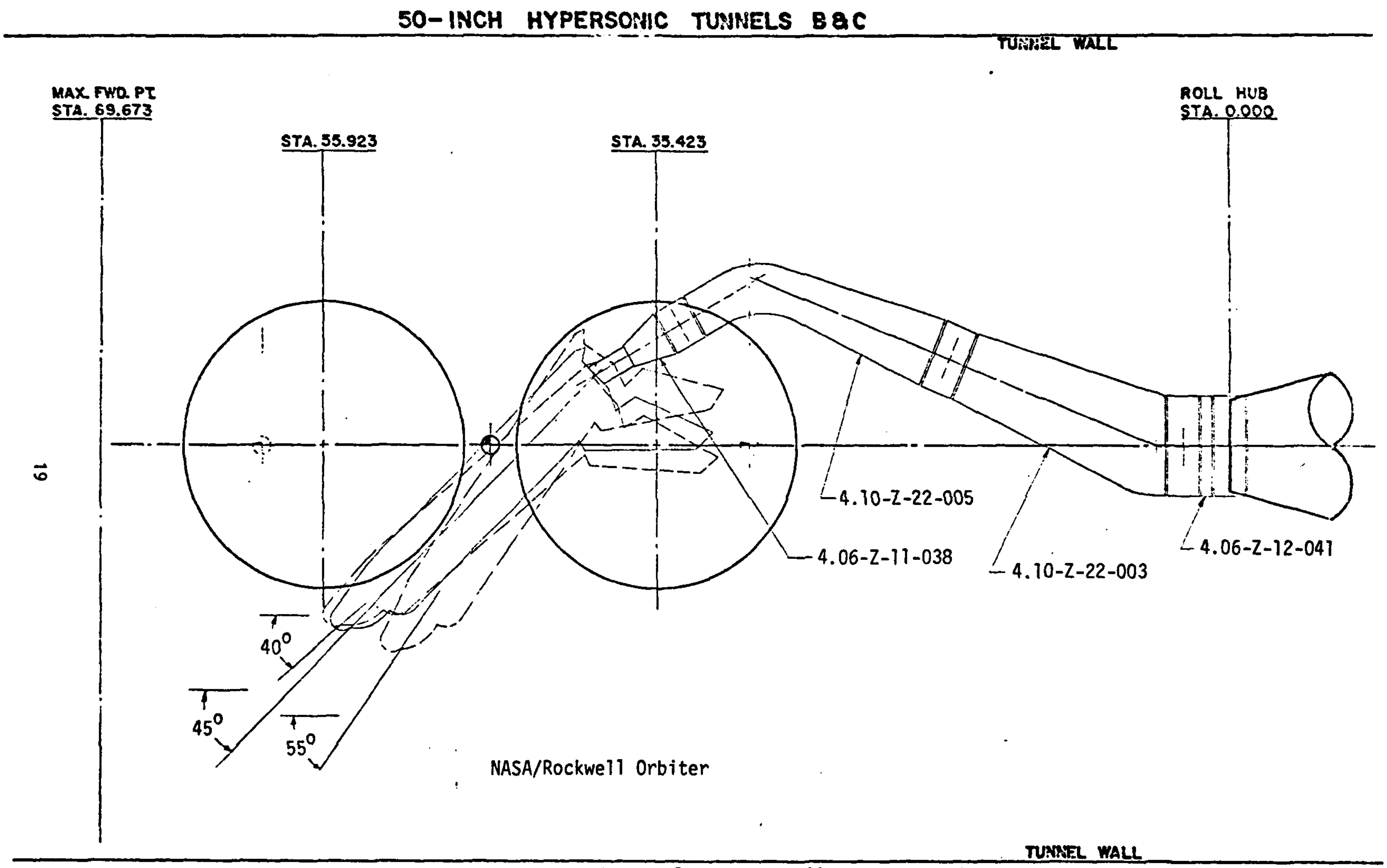



Figure 6. 56-0 Model Installation

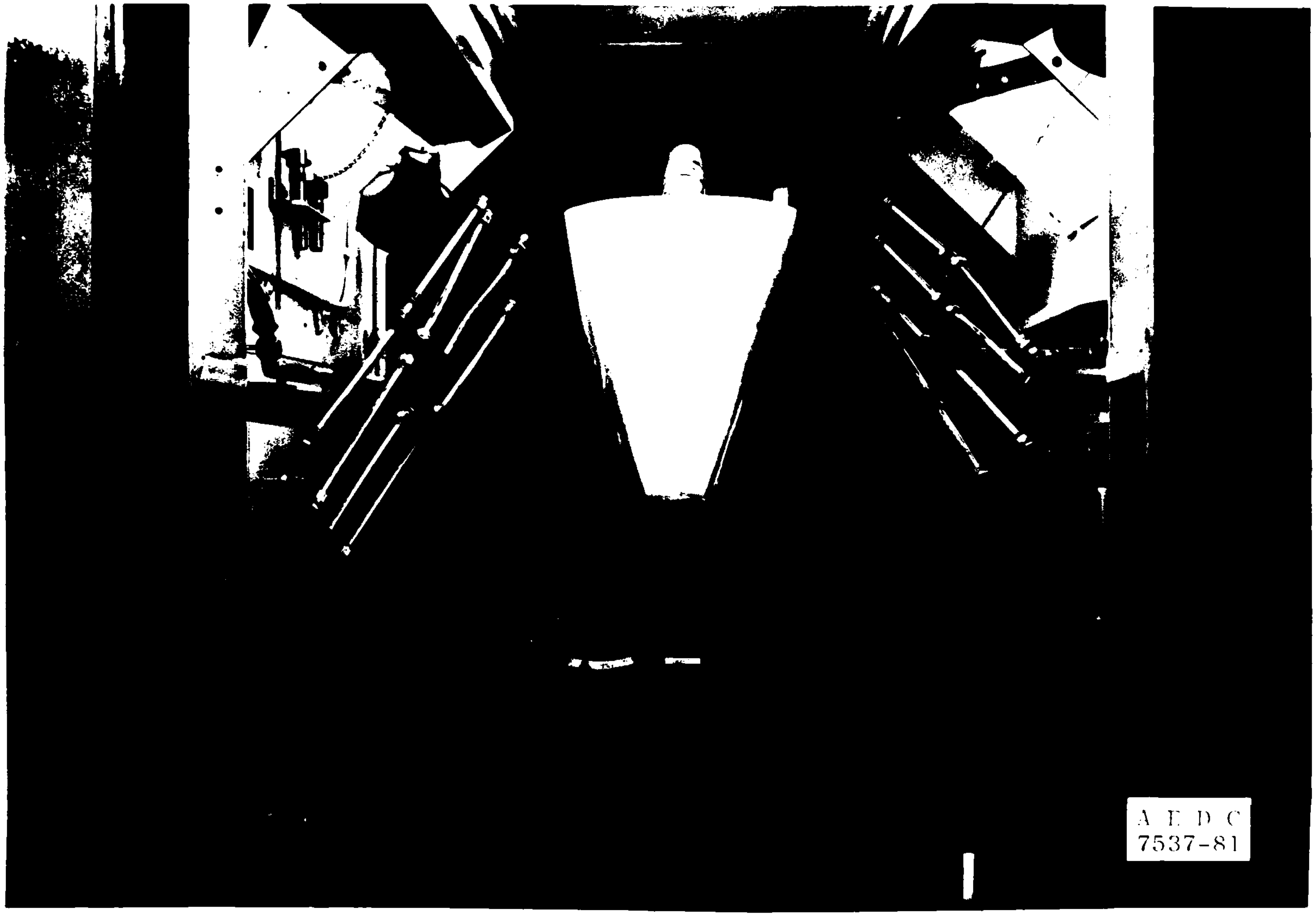



Figure 7. Installation Photograph of 83-0 Model

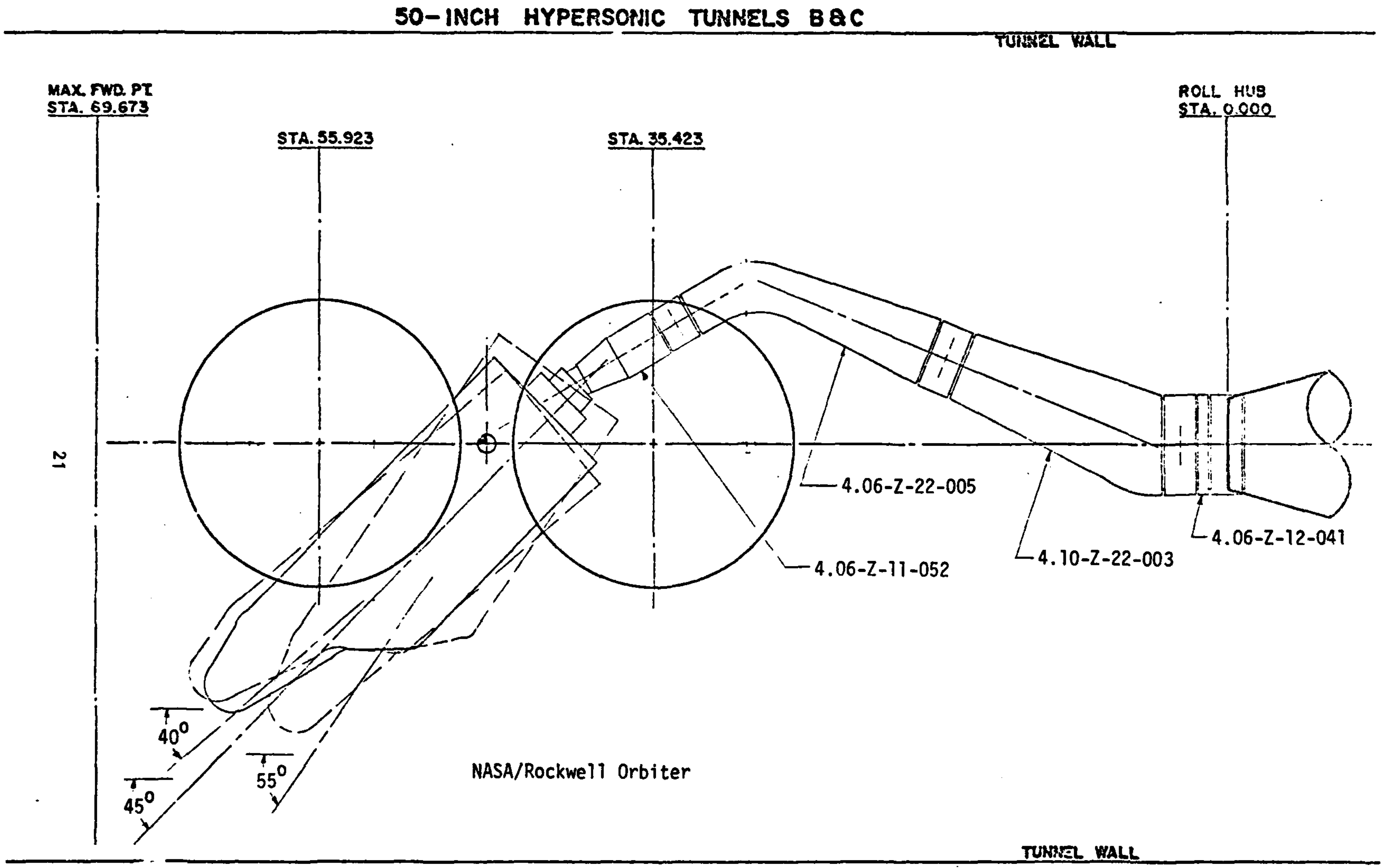



Figure 8. 83-0 Model Installation

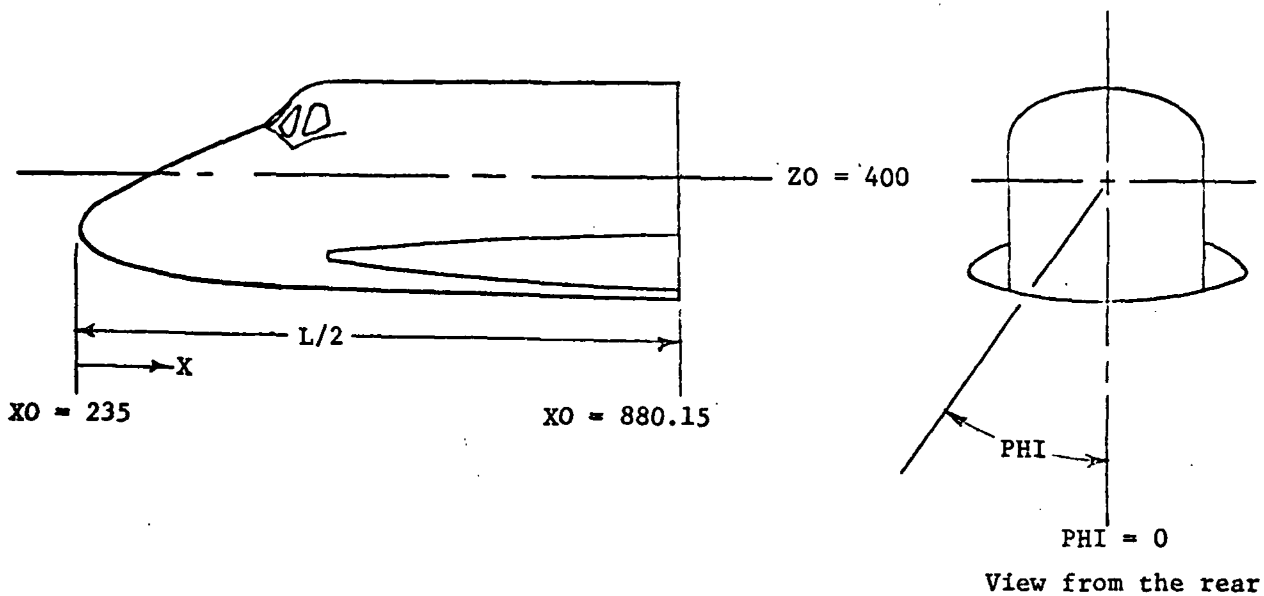
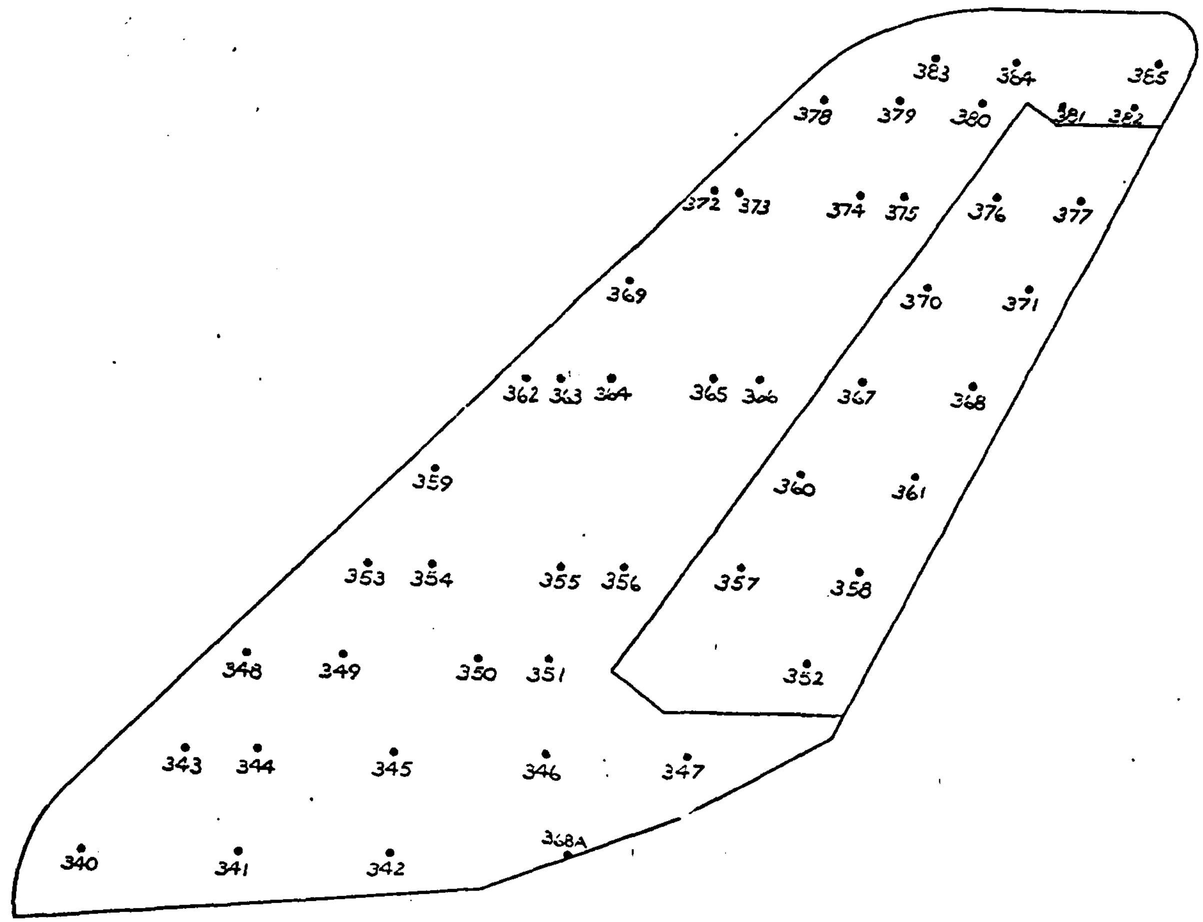
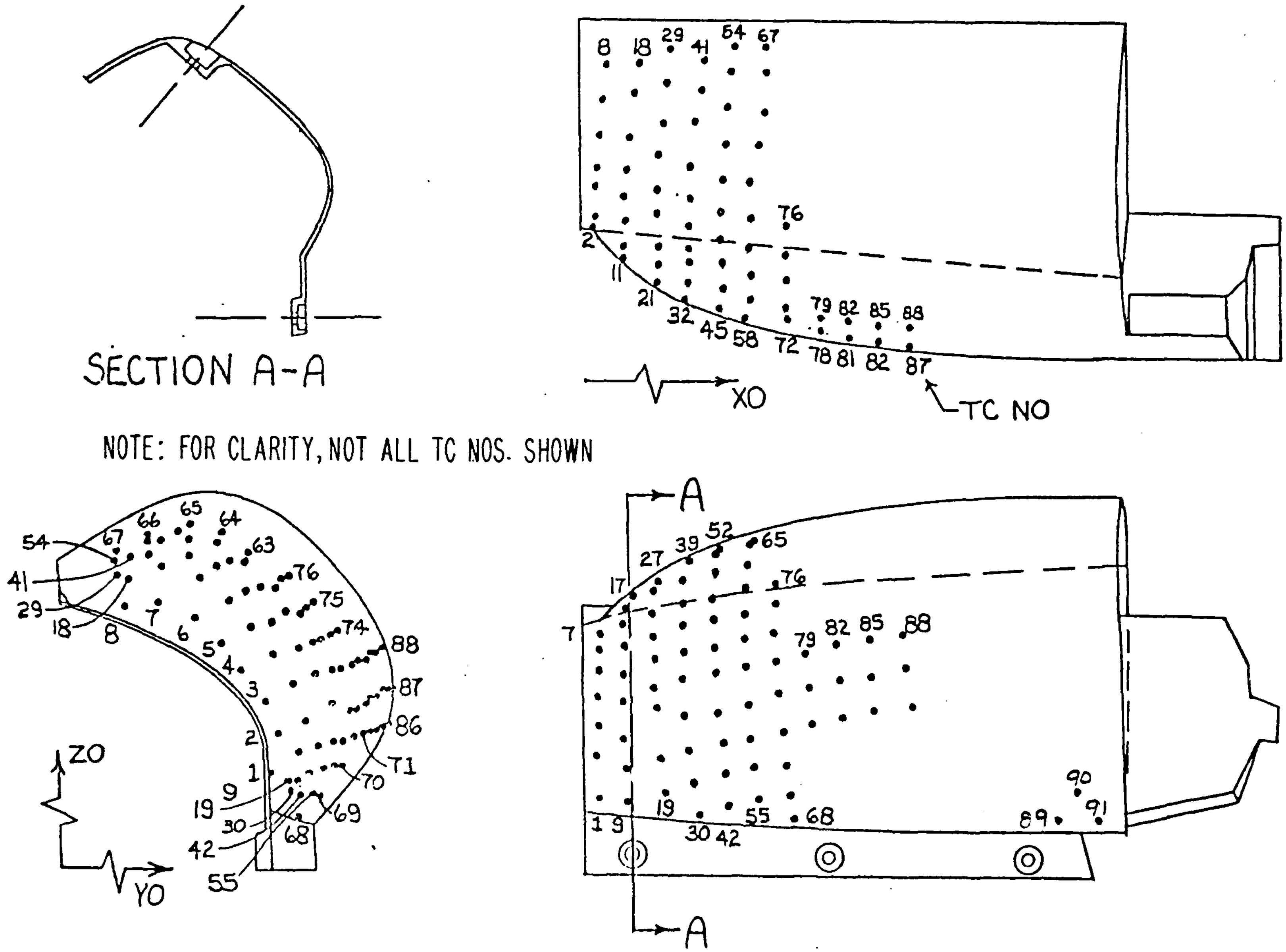



Fig. 9. Basic Dimensions and Coordinate System for the 83-0 Model

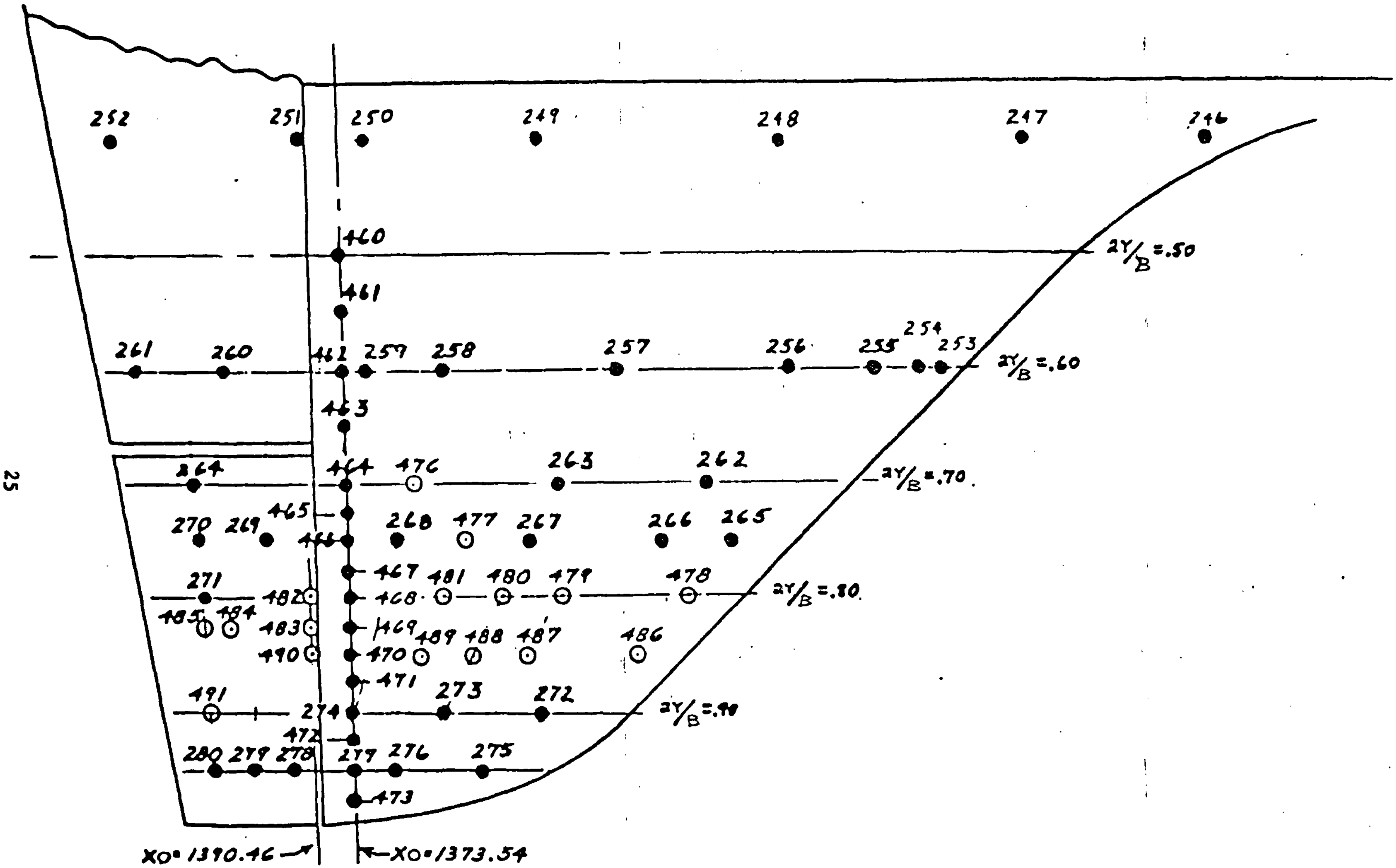



a. Vertical Tail

Fig. 10. Thermocouple Locations on 60-0 Model

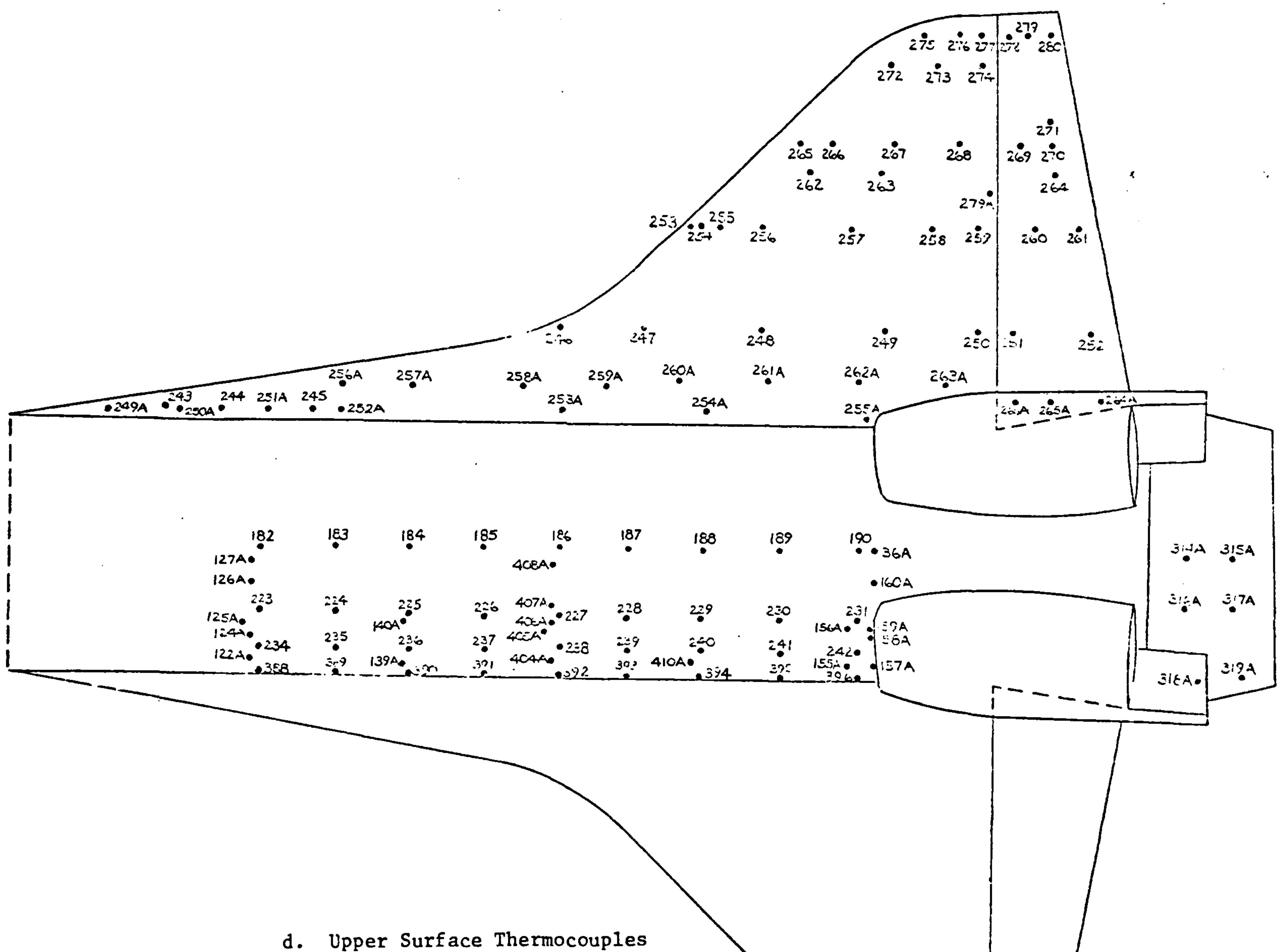



b. OMS Pod Thermocouple Locations
Fig. 10. Continued

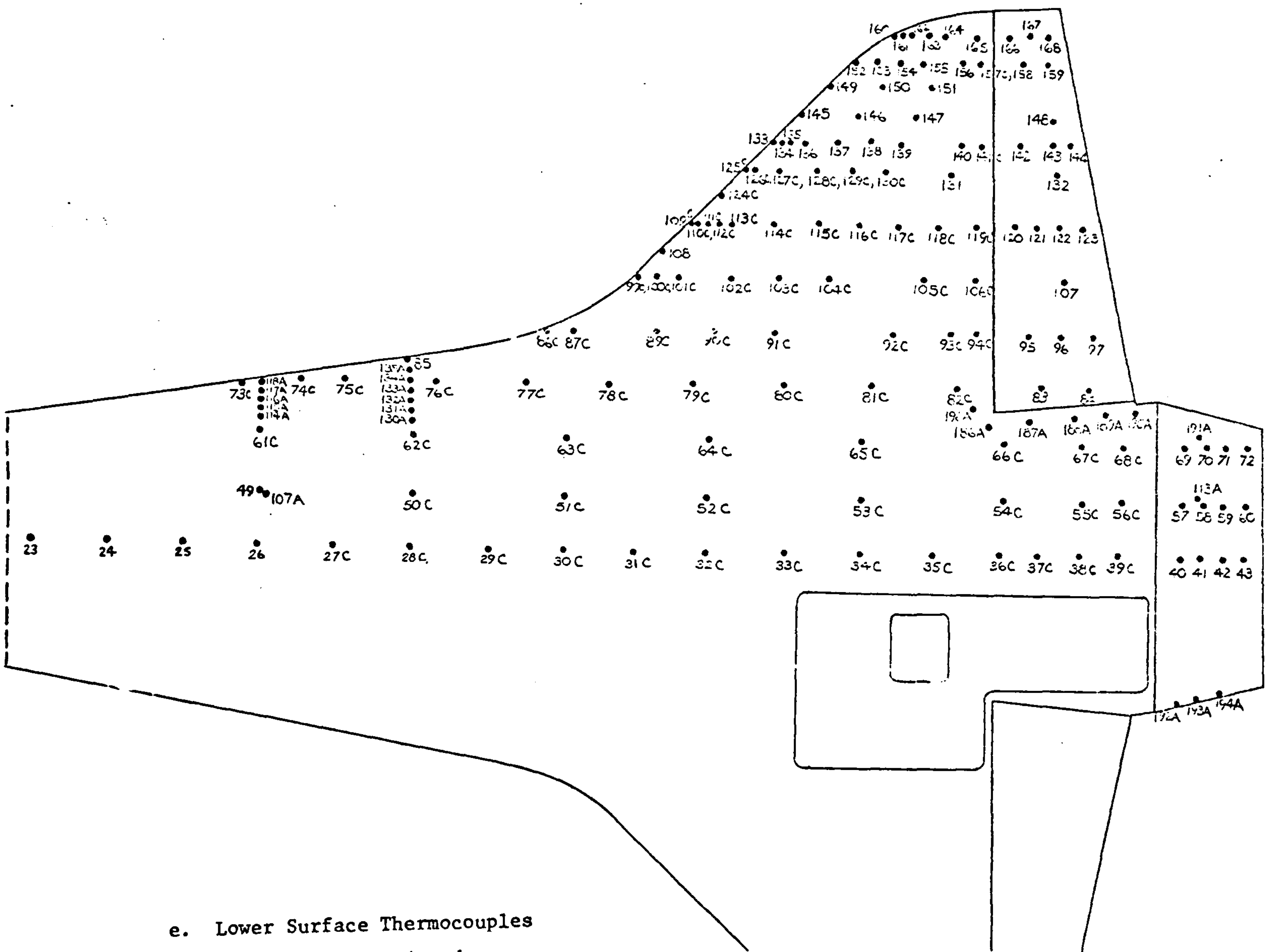



c. Upper Right Wing

Fig. 10. Continued

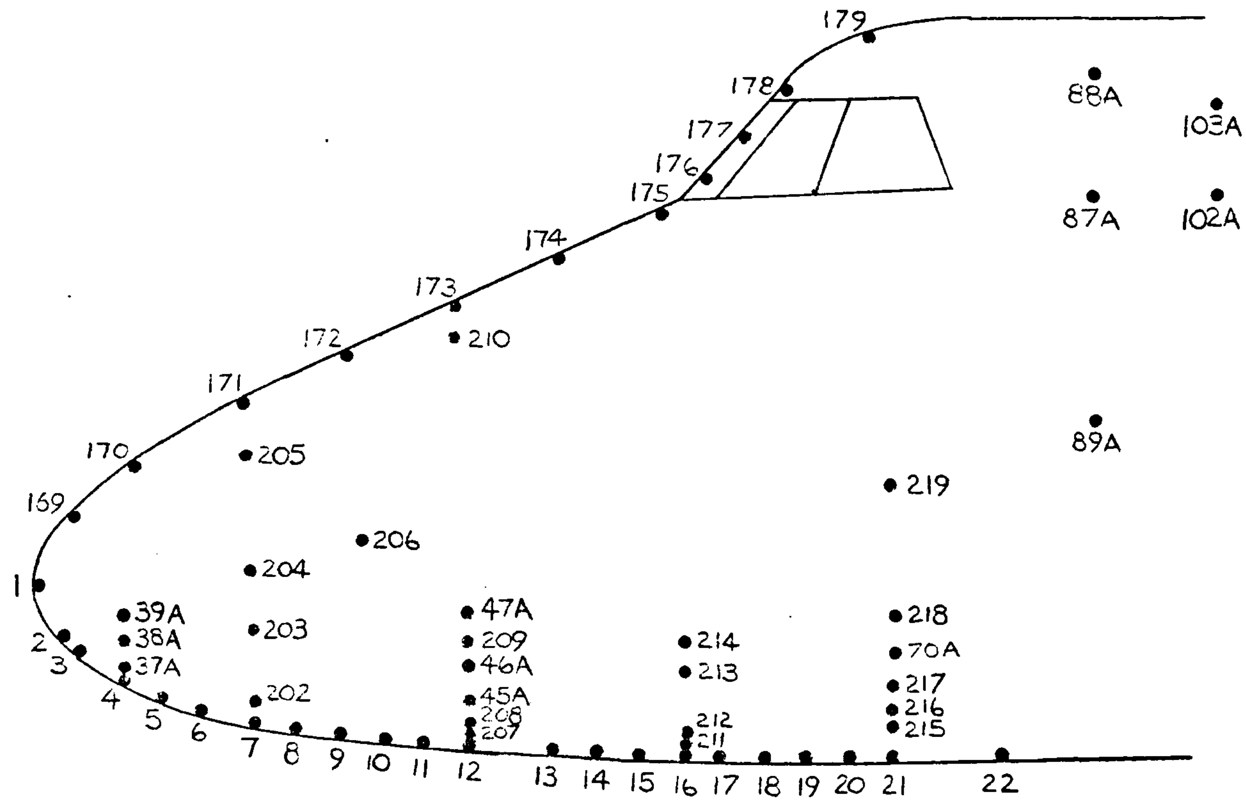



d. Upper Surface Thermocouples
Fig. 10. Continued



e. Lower Surface Thermocouples

Fig. 10. Continued




f. Forward Fuselage Side

Fig. 10. Concluded

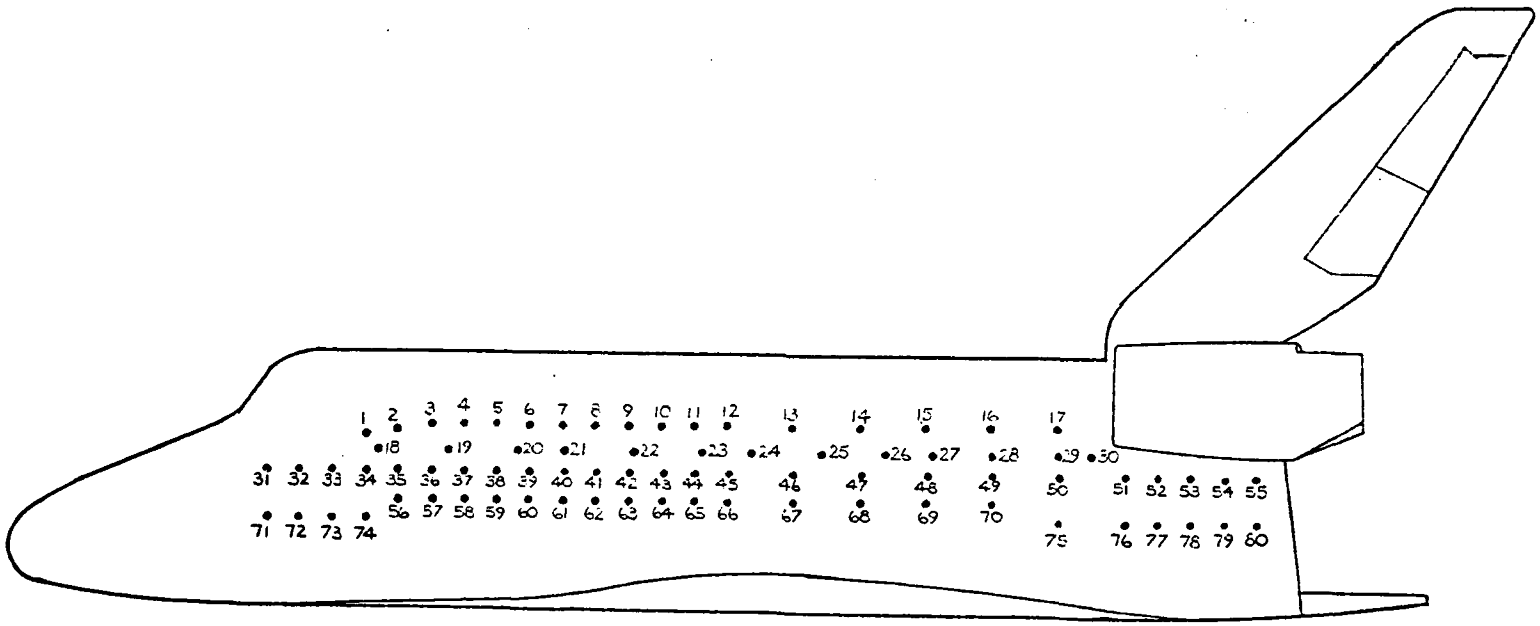
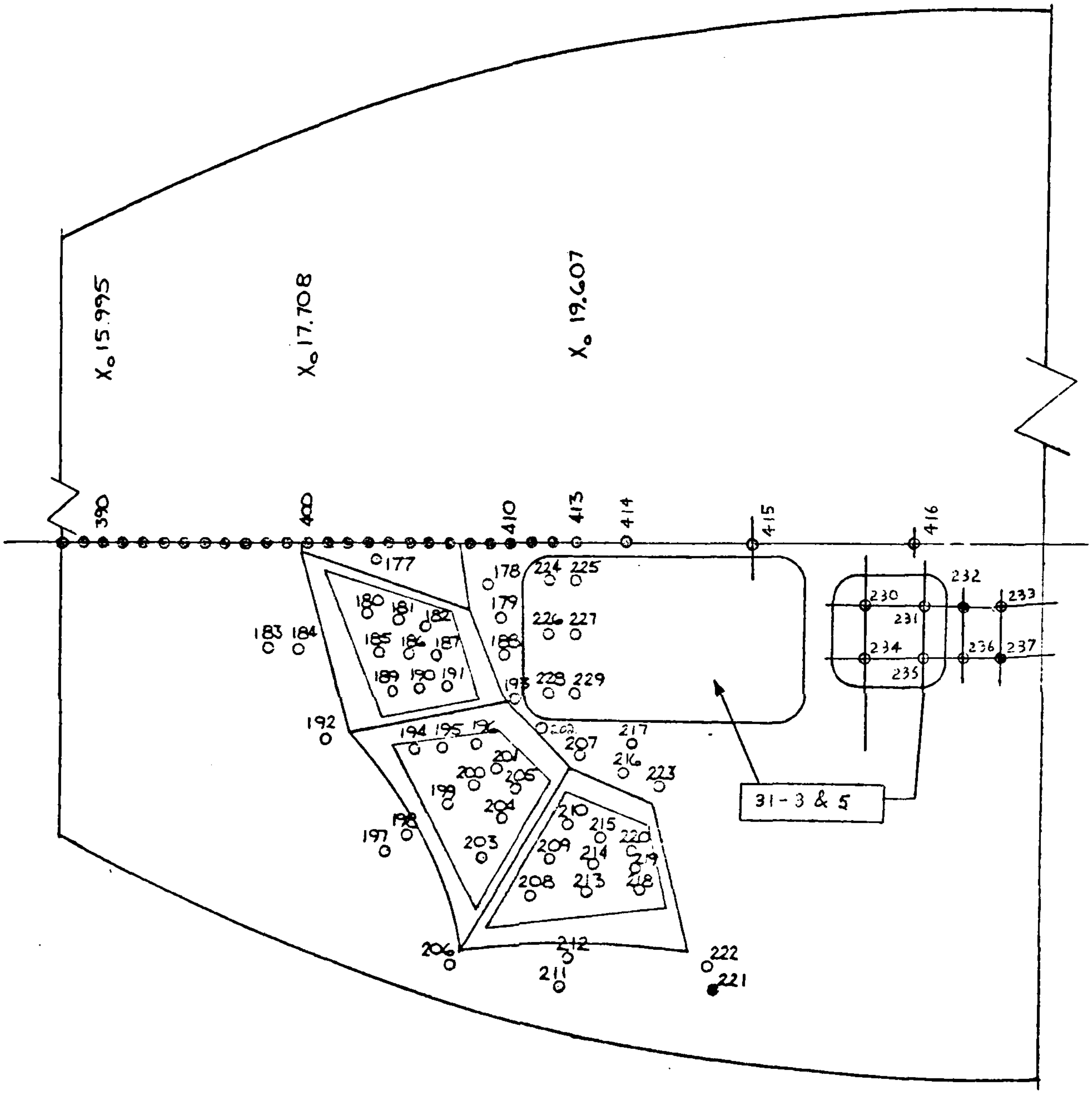
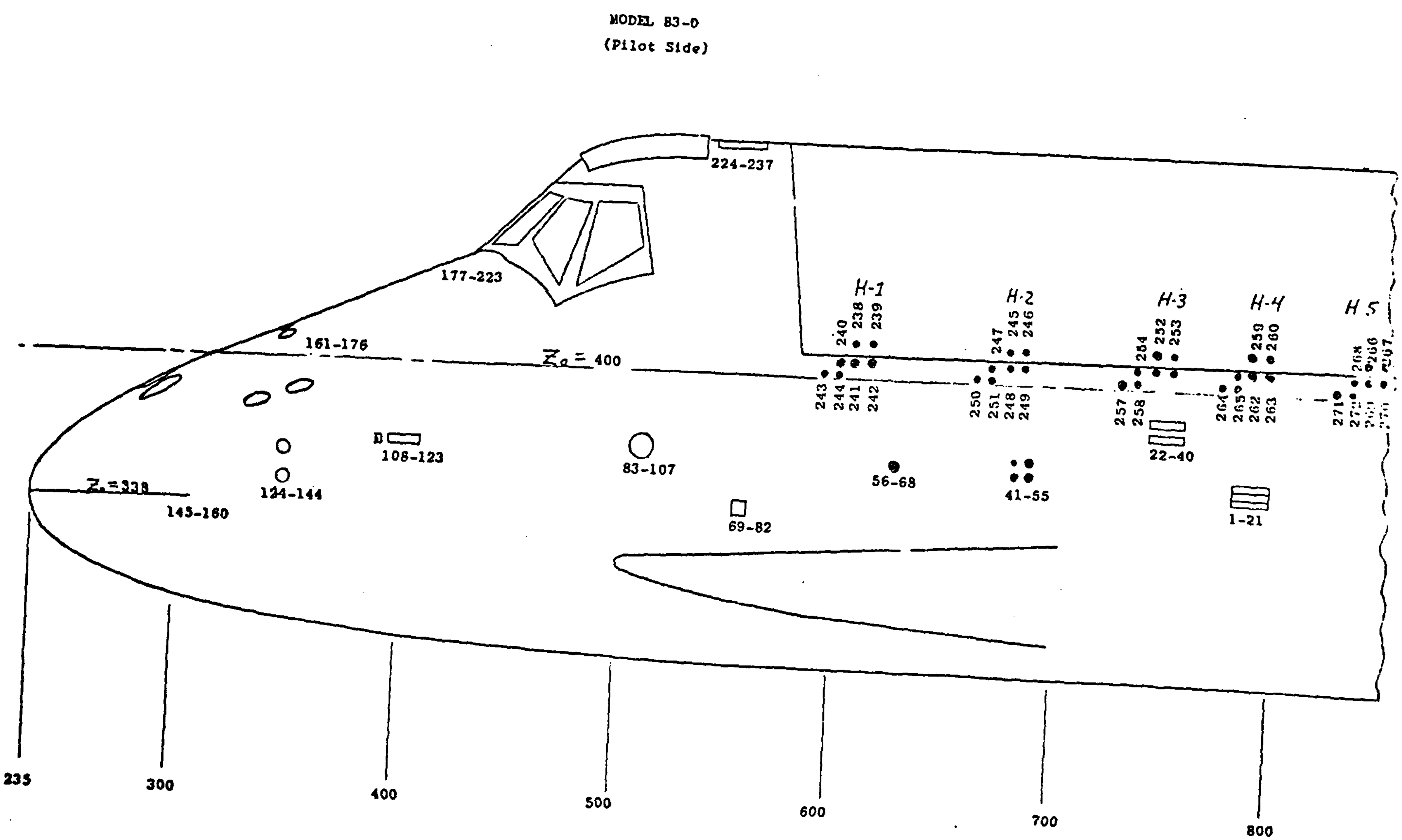



Fig. 11. Thermocouple Locations on 56-0 Model

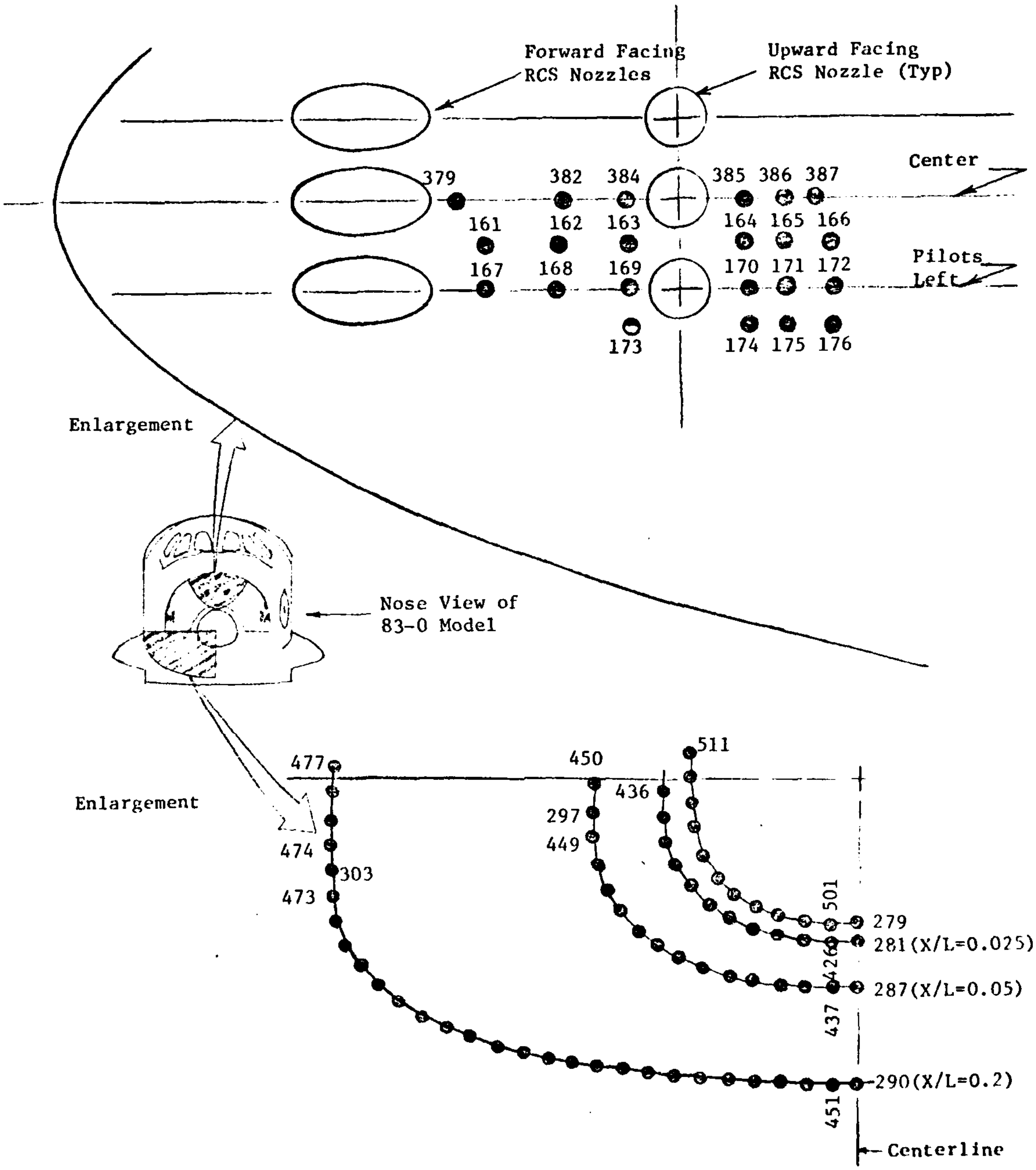


a. Canopy Thermocouple Locations
Fig. 12. Thermocouple Locations on 83-0 Model



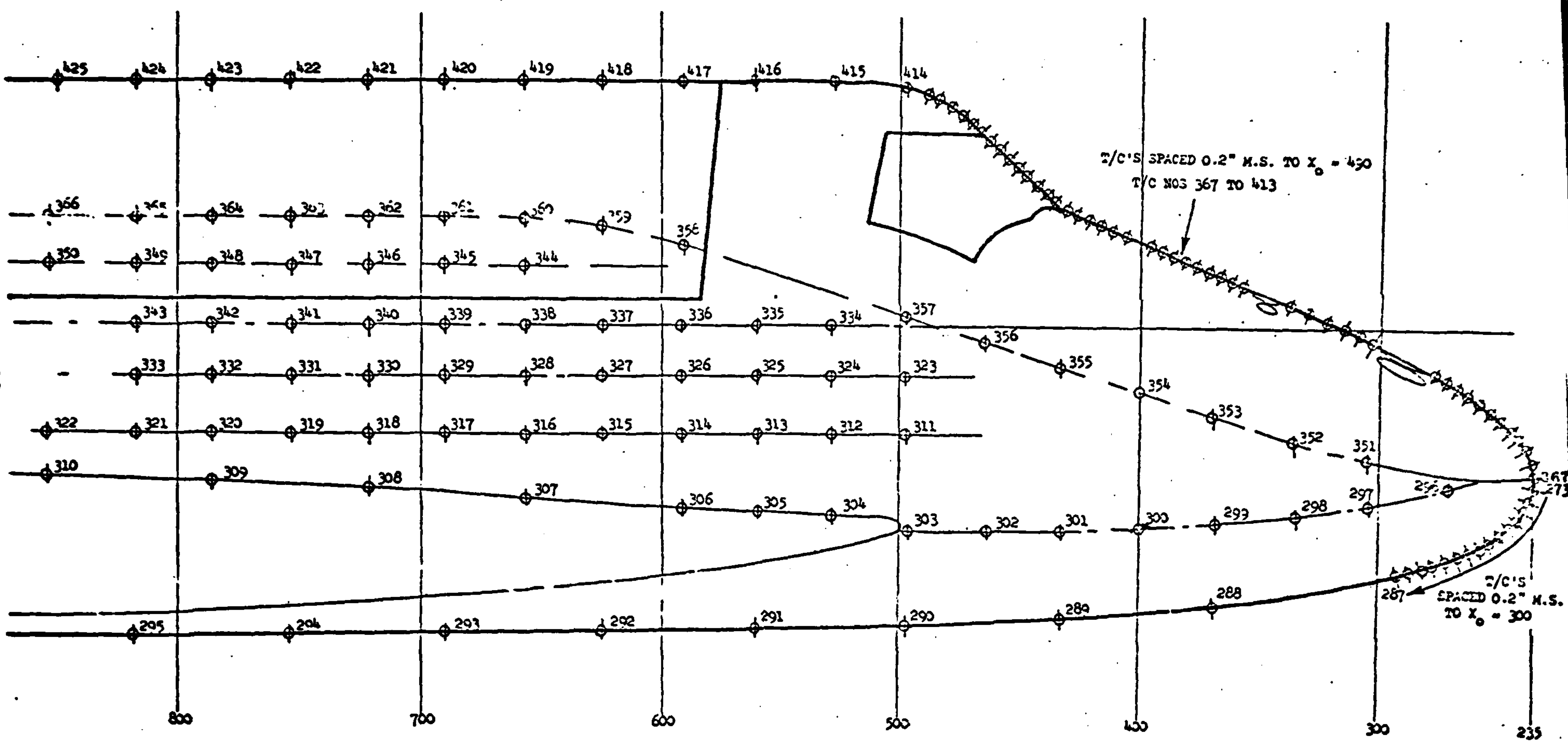

b. Thermocouple Locations on the Pilot Side

Fig. 12. Continued




c. Thermocouple Locations on Upper RCS Nozzles and Lower Fuselage

Figure 12. Continued




d. Thermocouple Locations on the Copilot Side

Fig. 12. Concluded

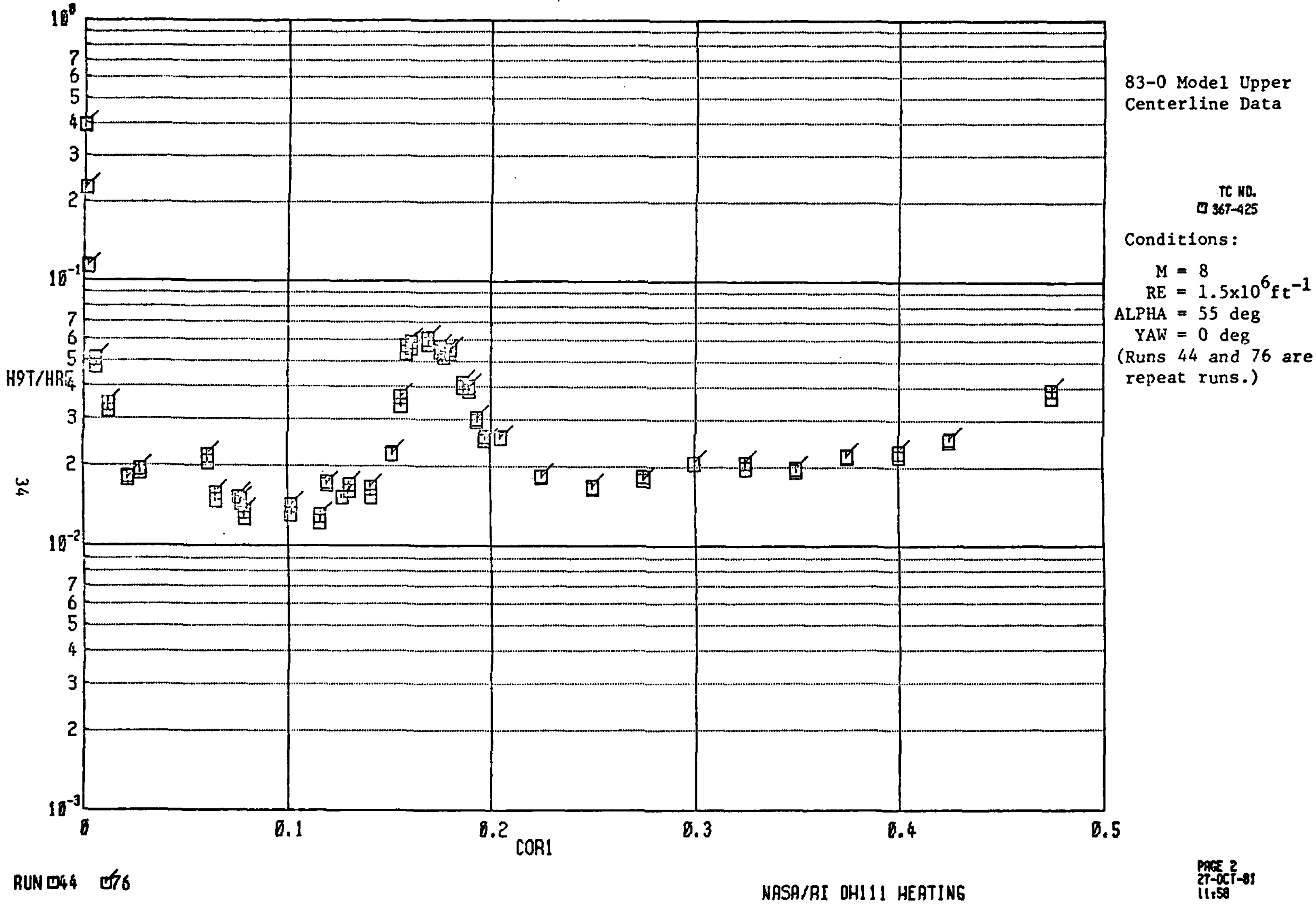
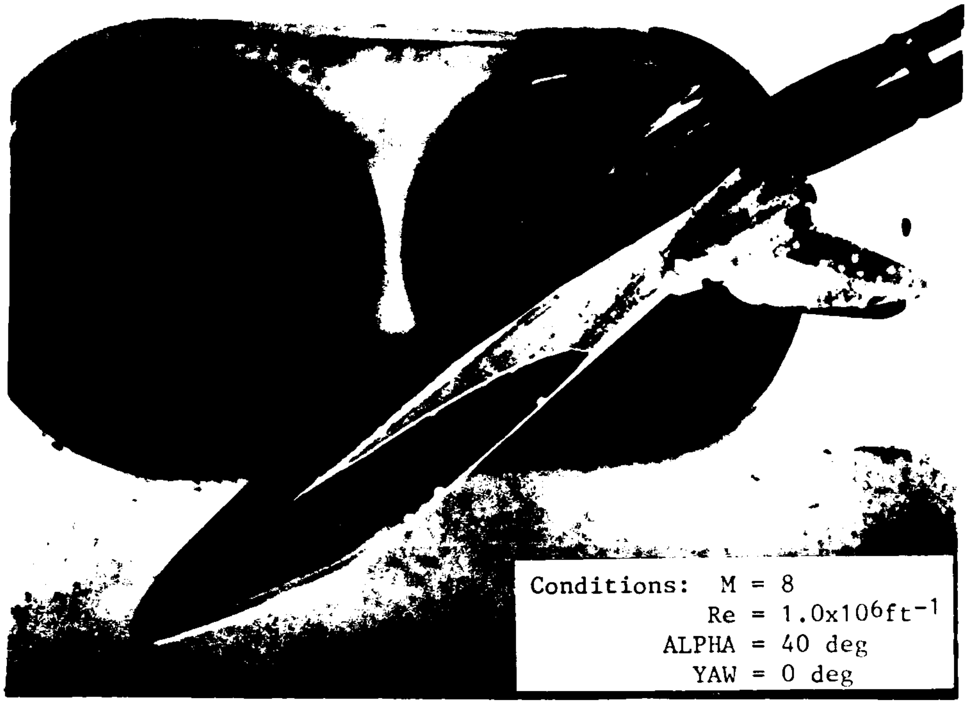



Figure 13. Thin-Skin Thermocouple Plotted Data

FLOW

Camera 2




FLOW

Camera 3

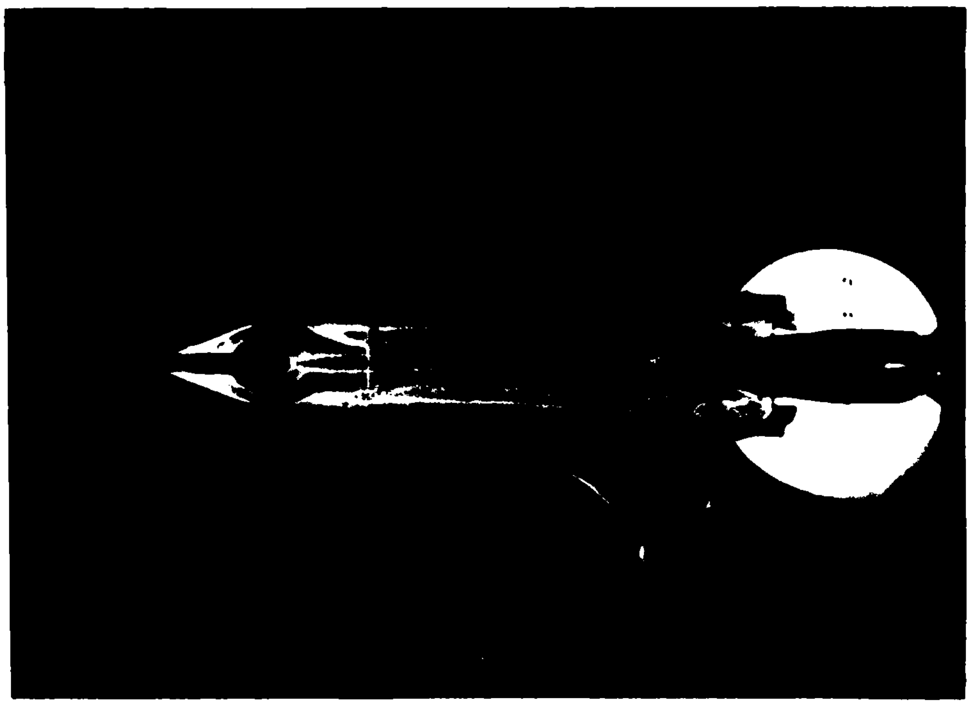


Figure 14. Oil-Flow Photographs on 60-0 Model (Run 262)

# APPENDIX II

## TABLES

TABLE 1. Data Transmittal Summary

**The following items were transmitted :**

| Item | Mrs. Dorothy B. Lee<br>NASA<br>Johnson Space Center ES3<br>Houston, TX 77058<br>No. of Copies | Mr. J. Gee<br>Rockwell International<br>Space Transportation and<br>Systems Group<br>Mail Code AC07<br>12214 Lakewood Blvd.<br>Downey, CA 90241<br>No. of Copies | Mr. Don Poucher<br>Chrysler Corp.<br>Space Division<br>P. O. Box 29200<br>Dept. 2734<br>New Orleans, LA<br>70189<br>No. of Copies | Mr. E. K. Hertzler<br>6510 TESTW/TEG<br>Stop 236<br>Edwards AFB, CA<br>93523<br>No. of Copies | Mr. R. D. Neumann<br>AFWAL/FIMG<br>Wright-Patterson AFB,<br>OH 45433<br>No. of Copies |
|---|---|---|---|---|---|
| **Test Summary Report** | 1 | 3 | | 1 | 1 |
| **83-0 Model: Heat Transfer and Oil Flow Tabulated Data (Runs 1-81)** | 1 | 3 | | 1 | 1 |
| **56-0 Model: Heat Transfer Tabulated Data (Runs 82-171)** | 1 | 3 | | 1 | 1 |
| **60-0 Model: Heat Transfer and Oil Flow Tabulated Data (Runs 172-269) Vols. 1 and 2 of 2** | 1 | 3 | | 1 | 1 |
| Magnetic Tape: Data from 83-0 56-0 and 60-0 (Runs 1-269) | | | 1 | | |
| **70 mm Schlieren Stills: Contact Prints and Duplicate Negatives (Runs 1-269)** | | 1 | | | |
| **70 mm Oil Flow Stills: Contact Prints and Duplicate Negatives, 83-0 (Runs 77-81, Rolls 627,630, 687,699), 60-0 (Runs 262-269, Rolls 716, 781, 792, 786)** | | 1 | | | |

TABLE 2. ESTIMATED UNCERTAINTIES

a. Basic Measurements

| Parameter Designation | STEADY-STATE ESTIMATED MEASUREMENT* Precision Index ±(S) Percent of Reading | Precision Index ±(S) Unit of Measurement | Precision Index ±(S) Degree of Freedom | Bias ±(B) Percent of Reading | Bias ±(B) Unit of Measurement | Uncertainty $\pm(B + t_{95}S)$ Percent of Reading | Uncertainty $\pm(B + t_{95}S)$ Unit of Measurement | Range | Type of Measuring Device | Type of Recording Device | Method of System Calibration |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ALPI, deg | | 0.025 | >30 | | | | 0.05 | ±11 | Potentiometer | Analog-to-digital converter into data acquisition system | Heidenhain rotary encoder RoD700 Resolution: 0.000 Overall accuracy: 0.001° |
| PHII, deg | | 0.15 | >30 | | | | 0.3 | ±90 | | | |
| PT, psia | | 0.02 | >30 | | 0.26 | | 0.3 | 0<P≤104 | Bell & Howell variable capacitance pressure transducer | Analog to Digital Converter into Data Acquisition System | In-place application of multiple pressure levels measured with a pressure measuring device calibrated in the standards laboratory |
| | | 0.02 | >30 | 0.25 | | ±(0.25% + .08 psi) | | 104<P<200 | | | |
| | | 0.11 | >30 | | 0.58 | | 0.80 | 200<P≤232 | | | |
| | | 0.11 | >30 | 0.25 | | ±(0.25% + 0.22 psi) | | 232<P≤ 1000 | | | |
| TIME, sec | | $5x10^{-4}$ | >30 | [(Runtime in sec) $(5x10^{-6})$] | | ± [(Runtime in sec) $(5x10^{-6})+10^{-3}$] sec | | milli-seconds to 365 days | Systron Donner time code reader | Digital Data Acquisition System | Instrument lab calibration against NBS |
| TT, °F | | 1 | >30 | 0.375 | | ±(0.375% + 2°F) | | 790-890 | Chromel®-Alumel® Thermocouple | Digital Thermometer into Digital Data Acquisition System | Thermocouple verification of NBS conformity/voltage substitution calibration |
| TW, °F | | 1 | >30 | | 2 | | 4 | 50-200 | FE-CN Thermocouple | Low Level Multiplexer into Analog to Digital Converter into Data Acquisition System | |
| | | 1 | >30 | | 2 | | 4 | 50-200 | CR-CN Thermocouple | | |

*Thompson, J. W. and Abernethy, R. B. et al. "Handbook Uncertainty in Gas Turbine Measurements." AEDC-TR-73-5 (AD 755356), February 1973.



GC-120 (2/81)

TABLE 2. Concluded

b. Calculated Parameters

| Parameter Designation | STEADY-STATE ESTIMATED MEASUREMENT* Precision Index ±(S) Percent of Reading | Precision Index ±(S) Unit of Measurement | Precision Index ±(S) Degree of Freedom | Bias ±(B) Percent of Reading | Bias ±(B) Unit of Measurement | Uncertainty ±(B + $t_{95}$S) Percent of Reading | Uncertainty ±(B + $t_{95}$S) Unit of Measurement | Range |
|---|---|---|---|---|---|---|---|---|
| M | | 0.020 | >30 | | 0+ | | 0.04 | 7.83 |
| | | 0.010 | | | 0+ | | 0.02 | 8.0 |
| RE, $ft^{-1}$ | 0.70 | | >30 | 0.56 | | 1.96 | | $0.5 \times 10^6 ft^{-1}$ |
| | 0.36 | | | 0.45 | | 1.17 | | $3.7 \times 10^6 ft^{-1}$ |
| H(TT), H(.9TT), H(.85TT), BTU/$ft^2$-sec-°R (Thin-skin thermocouple technique) | 1.0 | | >30 | 6.0 | | 8.0 | | $> 1 \times 10^{-3}$ |
| | 4.0 | | >30 | 6.0 | | 14.0 | | $1 \times 10^{-4} \rightarrow 1 \times 10^{-3}$ |
| | 7.0 | | >30 | 6.0 | | 20.0 | | $< 1 \times 10^{-4}$ |

*Abernethy, R. B. et al. and Thompson, J. W. "Handbook Uncertainty in Gas Turbine Measurements." AEDC-TR-73-5 (AD 755356), February 1973.
+Assumed to be zero

TABLE 3. 60-0 Model Thermocouple Coordinates

| Vertical Tail | | | |
|---|---|---|---|
| T/C | X/C | Z/BV | b,in. |
| 340 | 0.1 | 0.1 | 0.032 |
| 341 | 0.3 | 0.1 | 0.031 |
| 342 | 0.5 | 0.1 | 0.030 |
| 341 | 0.2 | 0.2 | 0.030 |
| 345 | 0.4 | 0.2 | 0.031 |
| 346 | 0.6 | 0.2 | 0.031 |
| 347 | 0.8 | 0.2 | 0.032 |
| 349 | 0.2 | 0.3 | 0.031 |
| 350 | 0.4 | 0.3 | 0.031 |
| 351 | 0.5 | 0.3 | 0.032 |
| 352 | 0.9 | 0.3 | 0.030 |
| 354 | 0.2 | 0.4 | 0.032 |
| 355 | 0.4 | 0.4 | 0.032 |
| 356 | 0.5 | 0.4 | 0.031 |
| 357 | 0.7 | 0.4 | 0.029 |
| 361 | 0.9 | 0.5 | 0.032 |
| 363 | 0.1 | 0.6 | 0.030 |
| 364 | 0.2 | 0.6 | 0.030 |
| 365 | 0.4 | 0.6 | 0.032 |
| 366 | 0.6 | 0.6 | 0.032 |
| 367 | 0.7 | 0.6 | 0.028 |
| 368 | 0.9 | 0.6 | 0.030 |
| 371 | 0.9 | 0.7 | 0.029 |
| 373 | 0.1 | 0.8 | 0.029 |
| 374 | 0.4 | 0.8 | 0.031 |

| Vertical Tail | | | |
|---|---|---|---|
| T/C | X/C | Z/BV | b,in. |
| 375 | 0.5 | 0.8 | 0.033 |
| 376 | 0.7 | 0.8 | 0.028 |
| 379 | 0.3 | 0.9 | 0.031 |
| 381 | 0.7 | 0.9 | 0.031 |
| 382 | 0.9 | 0.9 | 0.030 |
| 384 | 0.5 | 0.95 | 0.032 |
| 385 | 0.9 | 0.95 | 0.033 |

| OMS Pod | | | | |
|---|---|---|---|---|
| T/C | XO,in. | YO,in. | ZO,in. | b,in. |
| 1D | 1312.5 | 103.47 | 437.62 | 0.039 |
| 2D | 1312.5 | 105.65 | 451.57 | 0.025 |
| 3D | 1313.4 | 99.92 | 463.35 | 0.041 |
| 4D | 1314.2 | 90.04 | 474.41 | 0.043 |
| 5D | 1315.4 | 81.42 | 485.17 | 0.028 |
| 6D | 1316.2 | 69.87 | 492.67 | 0.027 |
| 8D | 1319.2 | 42.82 | 495.98 | 0.031 |
| 9D | 1322.7 | 113.14 | 434.29 | 0.023 |
| 10D | 1322.9 | 113.90 | 446.10 | 0.033 |
| 11D | 1323.2 | 115.62 | 459.73 | 0.029 |
| 12D | 1323.4 | 110.38 | 472.01 | 0.036 |
| 13D | 1324.9 | 101.55 | 482.44 | 0.031 |
| 14D | 1326.3 | 92.10 | 492.89 | 0.024 |
| 15D | 1327.3 | 80.93 | 501.43 | 0.026 |
| 16D | 1328.5 | 68.91 | 508.10 | 0.029 |
| 17D | 1331.3 | 54.30 | 510.38 | 0.029 |
| 18D | 1332.4 | 41.74 | 504.13 | 0.028 |
| 19D | 1336.5 | 114.14 | 437.45 | 0.027 |
| 20D | 1336.1 | 120.76 | 449.66 | 0.034 |
| 21D | 1336.0 | 124.01 | 462.41 | 0.026 |
| 22D | 1335.5 | 119.09 | 475.11 | 0.028 |
| 23D | 1336.8 | 110.33 | 485.84 | 0.030 |
| 24D | 1337.4 | 99.43 | 495.69 | 0.029 |
| 25D | 1338.4 | 88.08 | 504.61 | 0.031 |

| OMS Pod | | | | |
|---|---|---|---|---|
| T/C | XO,in. | YO,in | ZO,in. | b,in |
| 26D | 1339.9 | 76.58 | 512.79 | 0.030 |
| 27D | 1341.3 | 64.09 | 517.49 | 0.026 |
| 28D | 1343.2 | 50.13 | 514.51 | 0.030 |
| 29D | 1344.6 | 38.66 | 506.42 | 0.029 |
| 30D | 1348.9 | 111.69 | 427.05 | 0.015 |
| 31D | 1348.0 | 119.71 | 438.95 | 0.023 |
| 32D | 1346.9 | 126.40 | 451.59 | 0.029 |
| 34D | 1347.9 | 123.26 | 478.95 | 0.029 |
| 35D | 1348.6 | 114.89 | 488.55 | 0.031 |
| 36D | 1350.0 | 104.37 | 498.45 | 0.031 |
| 37D | 1350.9 | 93.15 | 507.16 | 0.032 |
| 38D | 1351.9 | 81.63 | 515.29 | 0.031 |
| 39D | 1353.3 | 68.97 | 521.19 | 0.029 |
| 40D | 1355.5 | 55.02 | 520.43 | 0.033 |
| 41D | 1356.8 | 42.84 | 512.69 | 0.028 |
| 42D | 1360.9 | 115.72 | 428.93 | 0.016 |
| 43D | 1360.7 | 124.34 | 441.15 | 0.023 |
| 44D | 1359.7 | 130.58 | 452.74 | 0.032 |
| 45D | 1359.5 | 133.66 | 466.33 | 0.033 |
| 46D | 1359.8 | 128.57 | 479.54 | 0.031 |
| 47D | 1360.0 | 119.66 | 489.71 | 0.029 |
| 48D | 1361.1 | 109.53 | 499.35 | 0.026 |
| 49D | 1362.4 | 98.70 | 508.42 | 0.027 |
| 50D | 1363.8 | 6[illegible].87 | 516.36 | 0.029 |

TABLE 3. Continued

| OMS Pod | | | | |
|---|---|---|---|---|
| T/C | XO,in. | YO,in. | ZO,in. | b,in. |
| 51D | 1365.3 | 74.61 | 524.20 | 0.030 |
| 52D | 1367.4 | 60.48 | 524.50 | 0.034 |
| 53D | 1369.0 | 48.26 | 518.62 | 0.030 |
| 54D | 1370.3 | 36.90 | 508.92 | 0.027 |
| 55D | 1373.1 | 120.67 | 431.05 | 0.019 |
| 56D | 1372.1 | 128.48 | 442.97 | 0.024 |
| 57D | 1371.2 | 134.78 | 454.73 | 0.033 |
| 58D | 1371.1 | 137.31 | 467.72 | 0.037 |
| 59D | 1372.0 | 132.02 | 481.22 | 0.034 |
| 60D | 1372.9 | 122.88 | 491.72 | 0.032 |
| 61D | 1373.7 | 112.41 | 501.33 | 0.029 |
| 62D | 1375.3 | 100.96 | 510.86 | 0.026 |
| 63D | 1376.4 | 89.49 | 519.21 | 0.024 |
| 64D | 1378.0 | 77.00 | 525.93 | 0.032 |
| 65D | 1379.7 | 63.26 | 527.07 | 0.036 |
| 67D | 1382.4 | 38.65 | 512.32 | 0.027 |
| 68D | 1385.9 | 115.78 | 421.02 | 0.020 |
| 69D | 1385.6 | 123.25 | 431.09 | 0.020 |
| 70D | 1383.9 | 131.73 | 443.72 | 0.025 |
| 71D | 1383.9 | 137.99 | 455.55 | 0.031 |
| 72D | 1383.3 | 140.31 | 469.43 | 0.036 |
| 73D | 1383.3 | 134.47 | 482.98 | 0.033 |
| 74D | 1384.2 | 125.46 | 493.31 | 0.031 |
| 75D | 1385.5 | 114.84 | 503.23 | 0.026 |

| OMS Pod | | | | |
|---|---|---|---|---|
| T/C | XO,in. | YO,in. | ZO,in | b,in. |
| 76D | 1386.9 | 104.23 | 511.85 | 0.025 |
| 77D | 1398.2 | 140.63 | 456.75 | 0.034 |
| 78D | 1395.7 | 142.72 | 471.17 | 0.040 |
| 79D | 1395.4 | 137.55 | 483.60 | 0.035 |
| 80D | 1407.8 | 143.07 | 458.22 | 0.035 |
| 81D | 1408.2 | 144.85 | 472.53 | 0.040 |
| 82D | 1408.3 | 138.82 | 486.10 | 0.035 |
| 83D | 1420.5 | 115.46 | 460.82 | 0.035 |
| 84D | 1420.3 | 146.41 | 474.10 | 0.040 |
| 85D | 1420.7 | 140.53 | 487.50 | 0.034 |
| 86D | 1433.1 | 147.19 | 461.84 | 0.034 |
| 87D | 1432.7 | 147.95 | 474.98 | 0.038 |
| 88D | 1433.3 | 142.34 | 488.33 | 0.031 |
| 89D | 1486.4 | 115.78 | 421.03 | 0.027 |
| 90D | 1494.5 | 123.25 | 431.10 | 0.029 |
| 91D | 1502.7 | 115.78 | 421.03 | 0.025 |

| Upper Fuselage | | | |
|---|---|---|---|
| T/C | X/L | PHI,deg | b,in. |
| 182 | 0.4 | 180 | 0.026 |
| 183 | 0.45 | 180 | 0.026 |
| 185 | 0.55 | 180 | 0.026 |
| 186 | 0.60 | 180 | 0.025 |
| 187 | 0.65 | 180 | 0.024 |
| 188 | 0.70 | 180 | 0.025 |
| 189 | 0.75 | 180 | 0.0255 |
| 223 | 0.40 | 157.5 | 0.034 |
| 224 | 0.45 | 157.5 | 0.034 |
| 225 | 0.50 | 157.5 | 0.034 |
| 226 | 0.55 | 157.5 | 0.035 |
| 227 | 0.60 | 157.5 | 0.034 |
| 228 | 0.65 | 157.5 | 0.0325 |
| 230 | 0.75 | 157.5 | 0.03 |
| 231 | 0.80 | 157.5 | 0.032 |
| 234 | 0.40 | 135.0 | 0.03 |
| 235 | 0.45 | 135.0 | 0.03 |
| 236 | 0.50 | 135.0 | 0.036 |
| 237 | 0.55 | 135 | 0.035 |
| 238 | 0.6 | 135 | 0.031 |
| 239 | 0.65 | 135 | 0.032 |
| 240 | 0.7 | 135 | 0.03 |
| 241 | 0.75 | 135 | 0.032 |
| 242 | 0.8 | 135 | 0.032 |
| 388 | 0.4 | 114 | 0.031 |
| 389 | 0.45 | 114 | 0.033 |

| Upper Fuselage | | | |
|---|---|---|---|
| T/C | X/L | PHI,deg | b,in. |
| 390 | 0.5 | 114 | 0.036 |
| 391 | 0.55 | 114 | 0.035 |
| 392 | 0.6 | 114 | 0.034 |
| 394 | 0.7 | 114 | 0.034 |
| 395 | 0.75 | 114 | 0.036 |
| T/C | X/L | Y,in. | b,in. |
| 124A | 0.397 | 1.128 | 0.031 |
| 125A | 0.396 | 8.68 | 0.029 |
| 139A | 0.496 | 1.584 | 0.034 |
| 410A | 0.695 | 1.572 | 0.033 |
| 155A | 0.790 | 1.572 | 0.031 |
| 156A | 0.790 | 0.868 | 0.026 |
| 157A | 0.819 | 1.582 | 0.031 |
| 158A | 0.819 | 1.218 | 0.025 |
| 159A | 0.819 | 0.868 | 0.028 |
| 160A | 0.819 | 0.308 | 0.031 |
| 36A | 0.817 | 0.014 | 0.028 |
| Forward Fuselage Side | | | |
| T/C | X/L | ZO,in. | b,in. |
| 205 | 0.05 | 378.4 | 0.033 |
| 210 | 0.10 | 410.0 | 0.037 |
| 206 | 0.076 | 350 | 0.035 |

## TABLE 3. Concluded

| Forward Fuselage Side | | | |
|---|---|---|---|
| T/C | X/L | Y,in. | b,in. |
| 207 | 0.10 | 0.086 | 0.038 |
| 88A | 0.247 | 1.101 | 0.026 |
| 89A | 0.248 | 0.672 | 0.031 |
| 102A | 0.296 | 1.638 | 0.023 |
| [illegible] | 0.2[illegible]6 | [illegible].667 | 0.015 |
| 70A | 0.199 | 1.681 | 0.030 |
| 45A | 0.099 | 1.041 | 0.028 |
| 46A | 0.099 | -- | 0.030 |
| 47A | 0.099 | 1.23 | 0.031 |
| 107A | 0.400 | 0.780 | 0.024 |

| Lower Centerline | | | |
|---|---|---|---|
| T/C | X/L | PHI,deg | b,in. |
| 2 | 0.005 | 0 | 0.032 |
| 4 | 0.020 | 0 | 0.040 |
| 7 | 0.050 | 0 | 0.033 |
| 12 | 0.10 | 0 | 0.037 |
| 16 | 0.150 | 0 | 0.036 |
| 21 | 0.200 | 0 | 0.035 |
| 26 | 0.400 | 0 | 0.034 |
| 27C | 0.450 | 0 | 0.033 |
| 29C | 0.550 | 0 | 0.030 |
| 30C | 0.600 | 0 | 0.030 |
| 32C | 0.700 | 0 | 0.029 |
| 34C | 0.800 | 0 | 0.030 |
| 36C | 0.900 | 0 | 0.031 |

| Lower Centerline | | | |
|---|---|---|---|
| T/C | X/L | PHI,deg | b,in. |
| 38C | 0.950 | 0 | 0.027 |
| 39C | 0.975 | 0 | 0.023 |
| 40 | 1.015 | 0 | 0.030 |
| 42 | 1.045 | 0 | 0.028 |

| Lower Wing | | | |
|---|---|---|---|
| T/C | X/L | YO,in. | b,in. |
| 50C | 0.5 | 46.8 | 0.028 |
| 51C | 0.6 | 46.8 | 0.025 |
| 52C | 0.7 | 46.8 | 0.030 |
| 53C | 0.8 | 46.8 | 0.030 |
| 54C | 0.9 | 46.8 | 0.028 |
| 56C | 0.975 | 46.8 | 0.028 |
| 58 | 1.030 | 46.8 | 0.030 |
| 60 | 1.06 | 46.8 | 0.031 |
| 62C | 0.5 | 93.6 | 0.031 |
| 64C | 0.7 | 93.6 | 0.029 |
| T/C | X/C | 2Y/B | b,in. |
| 75C | 0.1 | 0.3 | 0.026 |
| 80C | 0.6 | 0.3 | 0.030 |
| 83 | 0.9 | 0.3 | 0.030 |
| 84 | 0.95 | 0.3 | 0.031 |
| 87C | 0.05 | 0.4 | 0.031 |
| 96 | 0.9 | 0.4 | 0.026 |
| 113C | 0.1 | 0.6 | 0.031 |
| 114C | 0.2 | 0.6 | 0.031 |

| Lower Wing | | | |
|---|---|---|---|
| T/C | X/C | 2Y/B | b,in. |
| 116C | 0.4 | 0.6 | 0.032 |
| 117C | 0.5 | 0.6 | 0.032 |
| 118C | 0.6 | 0.6 | 0.032 |
| 129C | 0.3 | 0.7 | 0.036 |
| 130C | 0.4 | 0.7 | 0.035 |
| 107 | 0.9 | 0.5 | 0.029 |
| 120 | 0.8 | 0.6 | 0.030 |
| 121 | 0.85 | 0.6 | 0.0305 |
| 122 | 0.9 | 0.6 | 0.030 |
| 123 | 0.95 | 0.6 | 0.030 |
| 138 | 0.3 | 0.75 | 0.035 |
| 143 | 0.9 | 0.75 | 0.0305 |
| 144 | 0.95 | 0.75 | 0.030 |
| 147 | 0.4 | 0.80 | 0.031 |
| 148 | 0.9 | 0.80 | 0.0305 |
| 153 | 0.1 | 0.90 | 0.030 |
| 158 | 0.8 | 0.90 | 0.029 |
| 159 | 0.9 | 0.90 | 0.028 |
| 163 | 0.2 | 0.95 | 0.032 |
| 165 | 0.5 | 0.95 | 0.030 |
| 167 | 0.8 | 0.95 | 0.030 |
| 168 | 0.9 | 0.95 | 0.030 |

| Upper Wing | | | |
|---|---|---|---|
| T/C | X/C | 2Y/B | b,in. |
| 246 | 0.05 | 0.40 | 0.024 |
| 248 | 0.40 | 0.40 | 0.024 |
| 251 | 0.80 | 0.40 | 0.029 |
| 249A | 0.30 | - | 0.030 |
| 250 | 0.75 | 0.40 | 0.030 |
| 252 | 0.95 | 0.40 | 0.025 |
| 253 | 0.025 | 0.6 | 0.009 |
| 466 | 0.67 | 0.75 | 0.027 |
| 467 | 0.66 | 0.78 | 0.024 |
| 468 | 0.65 | 0.80 | 0.024 |
| 469 | 0.64 | 0.83 | 0.024 |
| 473 | 0.45 | 0.98 | 0.020 |
| 476 | 0.60 | 0.70 | 0.030 |
| 478 | 0.10 | 0.80 | 0.031 |
| 479 | 0.30 | 0.80 | 0.032 |
| 480 | 0.40 | 0.80 | 0.032 |
| 481 | 0.50 | 0.80 | 0.032 |
| 482 | 0.73 | 0.80 | 0.025 |

TABLE 4. 56-0 Model Thermocouple Coordinates

| Fuselage Side | | | |
|---|---|---|---|
| T/C | X/L | ZO, in. | b, in. |
| 1 | .275 | 437.5 | .0215 |
| 2 | .300 | 442.0 | .0210 |
| 3 | .325 | 445.0 | .0217 |
| 4 | .350 | 445.0 | .0215 |
| 5 | .375 | 445.0 | .0212 |
| 6 | .400 | 445.0 | .0217 |
| 7 | .425 | 445.0 | .0215 |
| 8 | .450 | 445.0 | .0218 |
| 9 | .475 | 445.0 | .0219 |
| 10 | .300 | 445.0 | .0220 |
| 11 | .525 | 445.0 | .0220 |
| 12 | .550 | 445.0 | .0222 |
| 13 | .600 | 445.0 | .0220 |
| 14 | .650 | 445.0 | .0220 |
| 15 | .700 | 445.0 | .0228 |
| 16 | .750 | 445.0 | .0220 |
| 17 | .800 | 445.0 | .0230 |
| 18 | .285 | 420.0 | .0190 |
| 19 | .337 | 420.0 | .0189 |
| 20 | .390 | 420.0 | .0189 |
| 21 | .426 | 420.0 | .0190 |
| 22 | .478 | 420.0 | .020 |
| 23 | .530 | 420.0 | .020 |
| 24 | .567 | 420.0 | .0205 |
| 25 | .620 | 420.0 | .0205 |

| Fuselage Side | | | |
|---|---|---|---|
| T/C | X/L | ZO, in. | b, in. |
| 26 | .670 | 420.0 | .0205 |
| 27 | .705 | 420.0 | .0207 |
| 28 | .750 | 420.0 | .0203 |
| 29 | .800 | 420.0 | .0202 |
| 30 | .824 | 420.0 | .0160 |
| 31 | .200 | 400.0 | .0210 |
| 32 | .225 | 400.0 | .0199 |
| 33 | .250 | 400.0 | .0199 |
| 34 | .275 | 400.0 | .0186 |
| 35 | .300 | 400.0 | .0180 |
| 36 | .325 | 400.0 | .0190 |
| 37 | .350 | 400.0 | .0192 |
| 38 | .375 | 400.0 | .0190 |
| 39 | .400 | 400.0 | .0139 |
| 40 | .425 | 400.0 | .0188 |
| 41 | .450 | 400.0 | .0195 |
| 42 | .475 | 400.0 | .0200 |
| 43 | .500 | 400.0 | .0200 |
| 44 | .525 | 400.0 | .0190 |
| 45 | .550 | 400.0 | .0200 |
| 46 | .600 | 400.0 | .0205 |
| 47 | .650 | 400.0 | .0210 |
| 48 | .700 | 400.0 | .0202 |
| 49 | .750 | 400.0 | .0205 |
| 50 | .800 | 400.0 | .0208 |

| Fuselage Side | | | |
|---|---|---|---|
| T/C | X/L | ZO, in. | b, in. |
| 51 | .850 | 400.0 | .0180 |
| 52 | .875 | 400.0 | .0180 |
| 53 | .900 | 400.0 | .0160 |
| 54 | .925 | 400.0 | .0170 |
| 55 | .950 | 400.0 | .0220 |
| 56 | .300 | 372.5 | .0170 |
| 57 | .325 | 372.5 | .0170 |
| 58 | .350 | 372.5 | .0170 |
| 59 | .375 | 372.5 | .0170 |
| 60 | .400 | 372.5 | .0170 |
| 61 | .425 | 372.5 | .0170 |
| 62 | .450 | 372.5 | .0172 |
| 63 | .475 | 372.5 | .0175 |
| 64 | .500 | 372.5 | .0180 |
| 65 | .525 | 372.5 | .0180 |
| 66 | .550 | 372.5 | .0190 |
| 67 | .600 | 372.5 | .0193 |
| 68 | .650 | 372.5 | .0190 |
| 69 | .700 | 327.2 | .0200 |
| 70 | .750 | 372.5 | .0200 |
| 71 | .200 | 355 | .0195 |
| 72 | .225 | 355 | .0190 |
| 73 | .250 | 355 | .0190 |
| 74 | .275 | 355 | .0180 |
| 75 | .800 | 355 | .0185 |

| Fuselage Side | | | |
|---|---|---|---|
| T/C | X/L | ZO, in. | b, in. |
| 76 | .850 | 355 | .0186 |
| 77 | .875 | 355 | .0170 |
| 78 | .900 | 355 | .0172 |
| 79 | .925 | 355 | .0180 |
| 80 | .950 | 355 | .0190 |

TABLE 5. 83-0 Model Thermocouple Coordinates

**Canopy**

| T/C | RH | LINE | YO,in | b,in |
|---|---|---|---|---|
| 177 | 1.0 | 4.0 | 0.0 | .030 |
| 178 | 1.0 | 6.0 | 0.0 | .044 |
| 179 | 2.0 | 6.0 | 0.0 | .047 |
| 180 | 3.0 | 3.0 | 14.0 | .029 |
| 181 | 3.0 | 4.0 | 15.0 | .030 |
| 182 | 3.0 | 5.0 | 17.0 | .032 |
| 183 | 4.0 | 1.0 | 0.0 | .028 |
| 184 | 4.0 | 2.0 | 0.0 | .031 |
| 185 | 4.0 | 3.0 | 22.0 | .027 |
| 186 | 4.0 | 4.0 | 22.0 | .028 |
| 187 | 4.0 | 5.0 | 22.0 | .030 |
| 188 | 4.0 | 6.0 | 0.0 | .059 |
| 189 | 5.0 | 3.0 | 30.0 | .032 |
| 190 | 5.0 | 4.0 | 30.0 | .032 |
| 191 | 5.0 | 5.0 | 29.0 | .034 |
| 192 | 6.0 | 2.0 | 0.0 | .032 |
| 193 | 6.0 | 6.0 | 0.0 | .043 |
| 194 | 7.0 | 3.0 | 41.0 | .029 |
| 195 | 7.0 | 4.0 | 41.0 | .028 |
| 196 | 7.0 | 5.0 | 40.0 | .029 |
| 197 | 8.0 | 1.0 | 0.0 | .022 |
| 198 | 8.0 | 2.0 | 0.0 | .026 |
| 199 | 8.0 | 3.0 | 51.0 | .030 |
| 200 | 8.0 | 4.0 | 47.0 | .032 |
| 201 | 8.0 | 5.0 | 44.0 | .032 |

**Canopy**

| T/C | RAY | LINE | YO,in. | b,in. |
|---|---|---|---|---|
| 202 | 8.0 | 6.0 | 0.0 | .028 |
| 203 | 9.0 | 3.0 | 62.0 | .028 |
| 204 | 9.0 | 4.0 | 56.0 | .035 |
| 205 | 9.0 | 5.0 | 49.0 | .035 |
| 206 | 10.0 | 2.0 | 0.0 | .030 |
| 207 | 10.0 | 6.0 | 0.0 | .030 |
| 208 | 11.0 | 3.0 | 71.0 | .030 |
| 209 | 11.0 | 4.0 | 64.0 | .031 |
| 211 | 12.0 | 1.0 | 0.0 | .028 |
| 212 | 12.0 | 2.0 | 0.0 | .030 |
| 213 | 12.0 | 3.0 | 70.0 | .030 |
| 215 | 12.0 | 5.0 | 0.0 | .032 |
| 216 | 12.0 | 6.0 | 0.0 | .032 |
| 217 | 12.0 | 7.0 | 0.0 | .032 |
| 218 | [illegible] | 3.0 | 69.0 | .031 |
| 219 | 13.0 | 4.0 | 65.0 | .032 |
| 220 | 13.0 | 5.0 | 62.0 | .031 |
| 222 | 14.0 | 2.0 | 0.0 | .028 |
| 223 | 14.0 | 6.0 | 0.0 | .030 |

**Canopy**

| T/C | X/L | ZO,in | b,in. |
|---|---|---|---|
| 224 | .197 | 485.0 | .023 |
| 225 | .197 | 490.0 | .027 |
| 226 | .197 | 485.0 | .024 |
| 227 | .197 | 490.0 | .033 |
| 228 | .193 | 485.0 | .029 |
| 229 | .197 | 490.0 | .029 |
| 230 | .242 | -- | .031 |
| 231 | .251 | -- | .032 |
| 233 | .261 | 572.0 | .034 |
| 234 | .242 | 547.5 | .031 |
| 235 | .251 | 559.5 | .031 |
| 236 | .257 | 567.0 | .033 |

**Cargo Bay Hinges**

| T/C | XO,in. | ZO,in. | b,in. |
|---|---|---|---|
| 238 | 602.3 | 420.0 | .030 |
| 239 | 602.3 | 420.0 | .030 |
| 243 | 602.3 | 405.0 | .027 |
| 244 | 602.3 | 405.0 | .026 |
| 245 | 669.8 | 420.0 | .032 |
| 246 | 669.8 | 420.0 | .032 |
| 247 | 669.8 | 415.0 | .033 |
| 248 | 669.8 | 415.0 | .033 |
| 249 | 669.8 | 415.0 | .033 |
| 250 | 669.8 | 405.0 | .028 |

**Cargo Bay Hinges**

| T/C | XO,in. | ZO,in. | b,in. |
|---|---|---|---|
| 251 | 660.8 | 405.0 | .028 |
| 253 | 737.3 | 420.0 | .033 |
| 254 | 737.3 | 415.0 | .034 |
| 255 | 737.3 | -- | .034 |
| 256 | 737.3 | -- | .034 |
| 258 | 737.3 | 405.0 | .031 |
| 260 | 783.5 | -- | .032 |
| 261 | 783.5 | -- | .033 |
| 264 | 783.5 | -- | .030 |
| 265 | 783.5 | -- | .030 |
| 266 | 850.6 | -- | .032 |
| 267 | 850.6 | -- | .032 |
| 268 | 850.6 | -- | .032 |
| 269 | 850.6 | -- | .032 |
| 270 | 850.6 | -- | .032 |
| 271 | 850.6 | -- | .029 |
| 272 | 850.6 | -- | .030 |

**Lower Fuselage**

| T/C | X/L | PHI,deg | b,in. |
|---|---|---|---|
| 426 | .025 | 350 | .021 |
| 427 | .025 | 343 | .022 |
| 428 | .025 | 335 | .024 |
| 429 | .025 | 324 | .026 |
| 430 | .025 | 320 | .028 |
| 432 | .025 | 303 | .029 |

## TABLE 5. Continued

**Lower Fuselage**

| T/C | X/L | PHI,deg | b,in. |
|---|---|---|---|
| 280 | .023 | | .021 |
| 434 | .025 | 287.5 | .029 |
| 435 | .025 | 280 | .029 |
| 436 | .025 | 273 | .030 |
| 437 | .051 | 352.5 | .025 |
| 438 | .05 | 347 | .026 |
| 439 | .05 | 339 | .025 |
| 440 | .05 | 334 | .024 |
| 441 | .05 | 327.5 | .024 |
| 442 | .05 | 321.5 | .028 |
| 443 | .05 | 318 | .028 |
| 445 | .05 | 306 | .026 |
| 446 | .05 | 300 | .025 |
| 447 | .05 | 295 | .023 |
| 448 | .05 | 289 | .028 |
| 449 | .05 | 284 | .026 |
| 452 | .20 | 351 | .023 |
| 453 | .20 | 346 | .023 |
| 454 | .20 | 342 | .023 |
| 455 | .20 | 338 | .023 |
| 456 | .20 | 333 | .023 |
| 457 | .20 | 330 | .023 |
| 458 | .20 | 326 | .024 |
| 459 | .20 | 322 | .026 |
| 460 | .20 | 320 | .026 |

**Lower Fuselage**

| T/C | X/L | PHI,deg | b,in. |
|---|---|---|---|
| 461 | .20 | 317 | .027 |
| 462 | .20 | 313.5 | .027 |
| 463 | .20 | 310.5 | .026 |
| 464 | .20 | 307 | .025 |
| 465 | .20 | 305 | .026 |
| 466 | .20 | 303 | .027 |
| 467 | .20 | 300.5 | .027 |
| 468 | .20 | 298 | .025 |
| 469 | .20 | 295 | .028 |
| 470 | .20 | 292 | .023 |
| 471 | .20 | 290 | .023 |
| 472 | .20 | 287 | .021 |
| 473 | .20 | 284 | .028 |
| 474 | .20 | 278 | .023 |
| 475 | .20 | 275.5 | .023 |
| 476 | .20 | 273 | .024 |

**Upper Fuselage**

| T/C | X/L | PHI,deg | b,in. |
|---|---|---|---|
| 367 | .0 | 180 | .026 |
| 368 | .001 | | .028 |
| 369 | .002 | | .026 |
| 371 | .006 | | .022 |
| 373 | .012 | | .029 |
| 376 | .022 | | .030 |
| 378 | .028 | | .026 |

**Upper Fuselage**

| T/C | X/L | PHI,deg | b,in. |
|---|---|---|---|
| 379 | .061 | 180 | .028 |
| 380 | .065 | | .023 |
| 381 | .068 | | .029 |
| 383 | .076 | | .030 |
| 384 | .077 | | .031 |
| 386 | .079 | | .027 |
| 387 | .102 | | .028 |
| 388 | .116 | | .021 |
| 389 | .119 | | .033 |
| 391 | .127 | | .036 |
| 392 | .131 | | .038 |
| 395 | .141 | | .034 |
| 398 | .152 | | .032 |
| 399 | .156 | | .030 |
| 400 | .158 | | .030 |
| 401 | .161 | | .029 |
| 403 | .166 | | .027 |
| 404 | .169 | | .027 |
| 406 | .175 | | .027 |
| 407 | .177 | | .0289 |
| 408 | .180 | | .033 |
| 410 | .186 | | .032 |
| 411 | .189 | | .037 |
| 412 | .193 | | .031 |
| 413 | .197 | | .030 |

**Upper Fuselage**

| T/C | X/L | PHI,deg | b,in. |
|---|---|---|---|
| 414 | .205 | 180 | .030 |
| 415 | .225 | | .022 |
| 416 | .25 | | .026 |
| 417 | .275 | | .033 |
| 418 | .300 | | .035 |
| 419 | .325 | | .033 |
| 420 | .350 | | .032 |
| 422 | .400 | | .033 |
| 423 | .425 | | .032 |
| 421 | .375 | | .033 |
| 425 | .475 | | .034 |

**Upper RCS Nozzles**

| T/C | X/L | YO,in. | b,in. |
|---|---|---|---|
| 161 | .062 | -7.5 | .027 |
| 162 | .071 | | .021 |
| 163 | .081 | | .028 |
| 164 | .094 | | .029 |
| 165 | .098 | | .028 |
| 166 | .101 | | .029 |
| 167 | .062 | -15.0 | .030 |
| 168 | .071 | | .024 |
| 169 | .081 | | .027 |
| 170 | .094 | | .028 |
| 171 | .098 | | .027 |
| 172 | .101 | | .029 |

# TABLE 5. Concluded

| Upper RCS Nozzle | | | |
|---|---|---|---|
| T/C | X/L | YO,in. | b,in. |
| 173 | .081 | -22.5 | .030 |
| 174 | .094 | -22.5 | .026 |
| 175 | .098 | -22.5 | .032 |
| 176 | .101 | -22.5 | .031 |
| **Fuselage Right Side** | | | |
| T/C | X/L | ZO,in. | b,in. |
| 296 | .025 | - | .029 |
| 297 | .05 | - | .027 |
| 298 | .075 | - | .027 |
| 299 | .10 | - | .028 |
| 307 | .325 | - | .025 |
| 301 | .15 | - | .028 |
| 302 | .175 | - | .031 |
| 303 | .20 | - | .028 |
| 304 | .225 | - | .021 |
| 305 | .250 | - | .028 |
| 306 | .275 | - | .034 |
| 310 | - | - | .027 |
| 311 | .200 | 355 | .023 |
| 312 | .225 | 355 | .025 |
| 313 | .250 | 355 | .030 |
| 314 | .275 | 355 | .0279 |
| 315 | .300 | 355 | .031 |
| 317 | .350 | 355 | .031 |
| 323 | .200 | 378 | .026 |

| Fuselage Right Side | | | |
|---|---|---|---|
| T/C | X/L | ZO,in. | b,in. |
| 324 | .225 | 378 | .027 |
| 325 | - | - | .028 |
| 326 | .275 | 378 | .026 |
| 327 | .300 | 378 | .029 |
| 328 | .325 | 378 | .025 |
| 334 | .225 | 400 | .026 |
| 335 | .250 | 400 | .029 |
| 336 | .275 | 400 | .026 |
| 337 | .300 | 400 | .031 |
| 338 | .325 | 400 | .027 |
| 344 | .325 | 425 | .031 |
| 345 | .350 | 425 | .030 |
| 346 | .375 | 425 | .030 |
| 347 | .400 | 425 | .030 |
| 349 | - | 425 | .031 |
| 351 | .05 | - | .027 |
| 352 | .075 | - | .027 |
| 353 | .10 | - | .026 |
| 354 | .125 | - | .027 |
| 355 | .15 | - | .027 |
| 356 | .175 | - | .031 |
| 357 | .20 | - | .026 |
| 358 | .275 | - | .032 |
| 359 | .30 | - | .031 |
| 360 | .325 | - | .030 |

| Fuselage Right Side | | | |
|---|---|---|---|
| T/C | X/L | | b,in. |
| 361 | .35 | - | .031 |
| 362 | .375 | - | .030 |
| 363 | .40 | - | .032 |
| 364 | .425 | - | .032 |
| **Lower Centerline** | | | |
| T/C | X/L | PHI,deg | b,in. |
| 273 | .001 | 0 | .029 |
| 274 | .0018 | | .029 |
| 275 | .004 | | .031 |
| 277 | .010 | | .029 |
| 281 | .026 | | .029 |
| 282 | .0299 | | .029 |
| 283 | .034 | | .030 |
| 285 | .0414 | | .029 |
| 286 | .0452 | | .027 |
| 288 | .10 | | .021 |
| 289 | .15 | | .033 |
| 291 | .25 | | .036 |

TABLE 6. Test Data Summary

a. Thin-Skin Thermocouple and Oil Flow Data Runs, 60-0 Model

| RE.x $10^{-6}$ $ft^{-1}$ | ALPHA, deg | YAW, deg | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 1 | 0.5 | 0 | -0.5 | -1 | -2 |
| 1.0 | 40 | 208 | 195 | 184 | 172,262* | 178 | 190,214 | 202 |
| 1.0 | 43 | 209 | 197 | 185 | 173,266* | 179 | 191 | 203 |
| 1.0 | 45 | 210 | 198 | 186 | 174,263* | 180 | 192 | 204 |
| 1.0 | 47 | 211 | 199 | | 175,267* | 181,187 | 193 | 205 |
| 1.0 | 50 | 212 | 200 | 188 | 176,2[illegible]4* | 182,268* | 194,269* | 206 |
| 1.0 | 55 | 213 | 201,215 | 189 | 177,265* | 183 | 196 | 207 |
| 0.5 | 40 | 255 | 240 | 228 | 216 | 222 | 234 | 246 |
| 0.5 | 43 | 256 | 241 | 229 | 217 | 223,252 | 235 | 247,261 |
| 0.5 | 45 | 257 | 242 | 230 | 218 | 224 | 236,254 | 248 |
| 0.5 | 47 | 258 | 243 | | 219 | 225,231,253 | 237 | 249 |
| 0.5 | 50 | 259 | 244 | 232 | 220 | 226 | 238 | 250 |
| 0.5 | 55 | 260 | 245 | 233 | 221 | 227 | 239 | 251 |

Run Number (Typical)

*Oil Flow

TABLE 6. Continued

b. Thin-Skin Thermocouple Data Runs, 56-0 Model

| RE x $10^{-6}$ $ft^{-1}$ | ALPHA, deg | YAW, deg | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 1 | 0.5 | 0 | -0.5 | -1 | -2 |
| 1.0 | 40 | | 103 | 93 | 82,105,113 | 88,168 | 98 | 109 |
| 1.0 | 43 | 117 | 104 | 94 | 83,164 | 89,169 | 99 | 110 |
| 1.0 | 45 | | | | 84,165 | | | |
| 1.0 | 47 | 118 | 106 | 95 | 85,166 | 90,170 | 100 | 111 |
| 1.0 | 50 | 119 | 107 | 96 | 86,114 | 91 | 101 | 112,116 |
| 1.0 | 55 | 120 | 108 | 97 | 87,167 | 92 | 102 | 115 |
| 0.5 | 40 | 157,171 | 147 | 135 | 121 | 129 | 140 | 152 |
| 0.5 | 43 | 158 | 148 | 136 | 122,127 | 131 | 141,145 | 153 |
| 0.5 | 45 | | | | 123,128 | | | |
| 0.5 | 47 | 159 | 149,162 | 137 | 124,130 | 132 | 142 | 154 |
| 0.5 | 50 | 160 | 150 | 138 | 125 | 133 | 143 | 155 |
| 0.5 | 55 | 161 | 151 | 139,163 | 126,144 | 134 | 146 | 156 |

TABLE 6. Concluded

c. Thin-Skin Thermocouple and Oil Flow Data Runs, 83-0 Model

| RE x $10^{-6}$ $ft^{-1}$ | ALPHA, deg | YAW, deg | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 1 | 0.5 | 0 | -0.5 | -1 | -2 |
| 1.0 | 40 | 32 | 22 | 12 | 1,9,77* | 6 | 17 | 27 |
| 1.0 | 43 | 33 | 23 | 13 | 2 | 7 | 18 | 28 |
| 1.0 | 45 | | | | 79* | | | |
| 1.0 | 47 | 34 | 24 | 14 | 3 | 8 | 19 | 29 |
| 1.0 | 50 | 35 | 25 | 15 | 4,80* | 10 | 20 | 30 |
| 1.0 | 55 | 36 | 26 | 16 | 5,78*,81* | 11 | 21 | 31,37 |
| 0.5 | 40 | | | | 38,39 | | | |
| 1.5 | 40 | 71 | 61 | 50 | 40 | 45 | 56 | 66 |
| 1.5 | 43 | 72 | 62 | 51 | 41 | 46 | 57 | 67 |
| 1.5 | 47 | 73 | 63 | 52 | 42 | 47 | 58 | 68 |
| 1.5 | 50 | 74 | 64 | 53 | 43 | 48 | 59 | 69 |
| 1.5 | 55 | 75 | 65 | 54,55 | 44,76 | 49 | 60 | 70 |

* Oil Flow

TABLE 7. Photographic Summary

| | | Camera Type | Frame Rate | Camera Location | View Type* | Roll No. | Run No. |
|---|---|---|---|---|---|---|---|
| **Schlieren** | **Camera 1** | Varitron 70 mm still | 1 per run | Operating side upstream window | Schlieren | 722,123<br>700,739 | 1-269 |
| | **Camera 2** | Varitron 70 mm still | 1 per run | Operating side downstream window | Schlieren | 729,147<br>774,798 | 1-269 |
| **Oil Flow** | **Camera 1** | Varitron 70 mm still | 1 per 2 sec ▲ | Top upstream window of 2-port window | View of model bottom surface on centerline | 627 | 77-81 |
| | | | | | | 716 | 262-269 |
| | **Camera 2** | Varitron 70 mm still | 1 per 2 sec ▲ | Operating side+ upstream window | View of copilot side of model on centerline | 630 | 77-81 |
| | | | | | | 781 | 262-269 |
| | **Camera 3** | Varitron 70 mm still | 1 per 2 sec ▲ | Tank | View of model top surface on centerline | 687 | 77-81 |
| | | | | | | 792 | 262-269 |
| | **Camera 4** | Varitron 70 mm still | 1 per 2 sec ▲ | Non-operating+ side upstream window | View of pilot side of model on centerline | 699 | 77-81 |
| | | | | | | 786 | 262-269 |

* Models were inverted

\+ Operating side is on the right looking downstream

▲ Runs 77 and 78 had a frame rate of 1 per sec

## APPENDIX III

### REFERENCE HEAT-TRANSFER COEFFICIENTS

In presenting heat-transfer coefficient results it is convenient to use reference coefficients to normalize the data. Equilibrium stagnation point values derived from the work of Fay and Riddell* were used to normalize the data obtained in this test. These reference coefficients are given by:

$$H(REF) = \frac{8.17173(PT2)^{1/2}(MUTT)^{0.4}\left[1 - \frac{P}{PT2}\right]^{0.25}\left[0.2235 + (1.35 \times 10^{-5})(TT+560)\right]}{(RN)^{1/2}(TT)^{0.15}}$$

and

$$STFR = \frac{H(REF)}{(RHO)(V)\ \left[0.2235 + (1.35 \times 10^{-5})(TT + 560)\right]}$$

where

| | |
|---|---|
| PT2 | Stagnation pressure downstream of a normal shock wave, psia |
| MUTT | Air viscosity based on TT, $lb_f\text{-sec/ft}^2$ |
| P | Free-stream pressure, psia |
| TT | Tunnel stilling chamber temperature, °R |
| RN | Reference nose radius, (0.0175 ft or 0.04 ft determined by model scale) |
| RHO | Free-stream density, $lbm/ft^3$ |
| V | Free-stream velocity, ft/sec |

*Fay, J. A. and Riddell, F. R. "Theory of Stagnation Point Heat Transfer in Dissociated Air," Journal of the Aeronautical Sciences, Vol. 25, No. 2, February 1958.

# APPENDIX IV

## SAMPLE TABULATED DATA

ARVIN/CALSPAN FIELD SERVICES, INC.
AEDC DIVISION
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
NASA/RI OH111 HEATING
PAGE 1

DATE COMPUTED 29-SEP-81
TIME COMPUTED 01:06:06
DATE RECORDED 29-SEP-81
TIME RECORDED 1: 5: 6
PROJECT NUMBER V B-1C

| RUN | MODEL | MACH NO | PT,PSIA | TT,DEGR | ALPPB | ALPI | PHII | ALPHA | YAW |
|---|---|---|---|---|---|---|---|---|---|
| 172 | 60-D | 7.88 | 203.5 | 1247.7 | 45.00 | 4.96 | 0.00 | 40.04 | 0.00 |

| T DEGR | P PSIA | Q PSIA | V FT/SEC | RHO LBM/FT3 | MU LB-SEC/FT2 | RE FT-1 | H(REF) (RN= 0.0175FT) | STFR (RN= 0.0175FT) |
|---|---|---|---|---|---|---|---|---|
| 93.01 | 0.023 | 1.000 | 3725. | 6.680E-04 | 7.485E-06 | 1.033E+06 | 2.449E-02 | 3.969E-02 |

| DELTAE | DELTAF | DELTASB |
|---|---|---|
| 0.0 | 0.0 | 0.0 |

| TC NO | TW DEG R | DTW/DT DEG/S | QDOT BTU/FT2-S | H(TT) BTU/FT2-S-DEG R | H(TT)/H(REF) | H(.9TT) BTU/FT2-S-DEG R | H(.9TT)/H(REF) | H(.85TT) BTU/FT2-S-DEG R | H(.85TT)/H(REF) | Vertical Tail X/C | Vertical Tail Z/BV | SKIN THICKNESS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 340 | 542.2 | 2.566 | 0.367 | 5.204E-04 | 0.0213 | 6.322E-04 | 0.0258 | 7.083E-04 | 0.0289 | 0.1000 | 0.1000 | 0.0315 |
| 341 | 540.9 | 0.955 | 0.131 | 1.848E-04 | 0.0075 | 2.244E-04 | 0.0092 | 2.513E-04 | 0.0103 | 0.3000 | 0.1000 | 0.0305 |
| 342 | 540.7 | 0.732 | 0.097 | 1.369E-04 | 0.0056 | 1.662E-04 | 0.0068 | 1.861E-04 | 0.0076 | 0.5000 | 0.1000 | 0.0295 |
| 344 | 540.6 | 0.934 | 0.126 | 1.767E-04 | 0.0073 | 2.170E-04 | 0.0089 | 2.430E-04 | 0.0099 | 0.2000 | 0.2000 | 0.0302 |
| 345 | 539.3 | 0.568 | 0.080 | 1.123E-04 | 0.0046 | 1.363E-04 | 0.0056 | 1.526E-04 | 0.0062 | 0.4000 | 0.2000 | 0.0313 |
| 346 | DELETE | | | | | | | | | | | |
| 347 | DELETE | | | | | | | | | | | |
| 349 | 539.0 | 0.572 | 0.079 | 1.119E-04 | 0.0046 | 1.358E-04 | 0.0055 | 1.521E-04 | 0.0062 | 0.2000 | 0.3000 | 0.0310 |
| 350 | 537.7 | 0.433 | 0.060 | 8.466E-05 | 0.0035 | 1.027E-04 | 0.0042 | 1.150E-04 | 0.0047 | 0.4000 | 0.3000 | 0.0310 |
| 351 | 536.5 | 0.390 | 0.055 | 7.794E-05 | 0.0032 | 9.458E-05 | 0.0039 | 1.058E-04 | 0.0043 | 0.5000 | 0.3000 | 0.0318 |
| 352 | 536.6 | 0.336 | 0.045 | 6.373E-05 | 0.0026 | 7.730E-05 | 0.0032 | 8.650E-05 | 0.0035 | 0.9000 | 0.3000 | 0.0300 |
| 354 | 537.5 | 0.425 | 0.060 | 8.432E-05 | 0.0034 | 1.023E-04 | 0.0042 | 1.145E-04 | 0.0047 | 0.2000 | 0.4000 | 0.0315 |
| 355 | DELETE | | | | | | | | | | | |
| 356 | 537.4 | 0.335 | 0.046 | 6.496E-05 | 0.0027 | 7.880E-05 | 0.0032 | 8.820E-05 | 0.0036 | 0.5000 | 0.4000 | 0.0308 |
| 357 | 537.2 | 0.393 | 0.051 | 7.171E-05 | 0.0029 | 8.699E-05 | 0.0036 | 9.736E-05 | 0.0040 | 0.7000 | 0.4000 | 0.0290 |
| 361 | 537.7 | 0.653 | 0.092 | 1.297E-04 | 0.0053 | 1.574E-04 | 0.0064 | 1.762E-04 | 0.0072 | 0.9000 | 0.5000 | 0.0315 |
| 363 | 541.9 | 1.849 | 0.218 | 3.090E-04 | 0.0126 | 3.753E-04 | 0.0153 | 4.205E-04 | 0.0172 | 0.1000 | 0.6000 | 0.0295 |
| 364 | 540.7 | 0.765 | 0.107 | 1.508E-04 | 0.0062 | 1.831E-04 | 0.0075 | 2.050E-04 | 0.0084 | 0.2000 | 0.6000 | 0.0303 |
| 365 | 540.0 | 0.480 | 0.068 | 9.667E-05 | 0.0039 | 1.174E-04 | 0.0048 | 1.314E-04 | 0.0054 | 0.4000 | 0.6000 | 0.0318 |
| 366 | 539.9 | 0.369 | 0.052 | 7.340E-05 | 0.0030 | 8.918E-05 | 0.0036 | 9.987E-05 | 0.0041 | 0.5000 | 0.6000 | 0.0315 |
| 367 | 539.6 | 0.413 | 0.052 | 7.314E-05 | 0.0030 | 8.876E-05 | 0.0036 | 9.941E-05 | 0.0041 | 0.7000 | 0.6000 | 0.0286 |
| 368 | DELETE | | | | | | | | | | | |
| 371 | DELETE | | | | | | | | | | | |
| 373 | 543.7 | 2.768 | 0.367 | 5.209E-04 | 0.0213 | 6.331E-04 | 0.0259 | 7.096E-04 | 0.0290 | 0.1000 | 0.8000 | 0.0293 |
| 374 | 540.1 | 0.969 | 0.135 | 1.902E-04 | 0.0078 | 2.309E-04 | 0.0094 | 2.588E-04 | 0.0106 | 0.4000 | 0.8000 | 0.0310 |
| 375 | 536.8 | 0.653 | 0.095 | 1.341E-04 | 0.0055 | 1.627E-04 | 0.0066 | 1.822E-04 | 0.0074 | 0.5000 | 0.8000 | 0.0325 |
| 376 | 536.5 | 0.580 | 0.070 | 9.901E-05 | 0.0040 | 1.201E-04 | 0.0049 | 1.345E-04 | 0.0055 | 0.7000 | 0.8000 | 0.0280 |
| 379 | 540.4 | 1.504 | 0.214 | 3.021E-04 | 0.0123 | 3.6[illegible]E-04 | 0.0150 | 4.109E-04 | 0.0168 | 0.3000 | 0.5000 | 0.0305 |
| 380 | 538.2 | 0.666 | 0.092 | 1.273E-04 | 0.0053 | 1.569E-04 | 0.0064 | 1.757E-04 | 0.0072 | 0.7000 | 0.9000 | 0.0308 |
| 382 | 538.8 | 0.944 | 0.126 | 1.777E-04 | 0.0073 | 2.157E-04 | 0.0088 | 2.414E-04 | 0.0099 | 0.9000 | 0.9000 | 0.0296 |
| 384 | 539.6 | 1.303 | 0.184 | 2.596E-04 | 0.0106 | 3.151E-04 | 0.0129 | 3.528E-04 | 0.0144 | 0.5000 | 0.9500 | 0.0315 |
| 385 | 539.0 | 1.172 | 0.173 | 2.444E-04 | 0.0100 | 2.967E-04 | 0.0121 | 3.322E-04 | 0.0136 | 0.9000 | 0.9500 | 0.0330 |
| 1D | DELETE | | | | | | | | | | | |

1. Thin-Skin Thermocouple Tabulated Data

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7-8